CHEMICAL ENGINEERING

ESSENTIALS FOR THE CPI PROFESSIONAL

www.chemengonline.com

December 2021

Pumps

Column Internals

Cake Filtration

High-Cycle Valves in RTOs

Motors and Drives

Plant Revamps

page 26

Chemical Engineering Buyer's Guide 2022

Access Intelligence

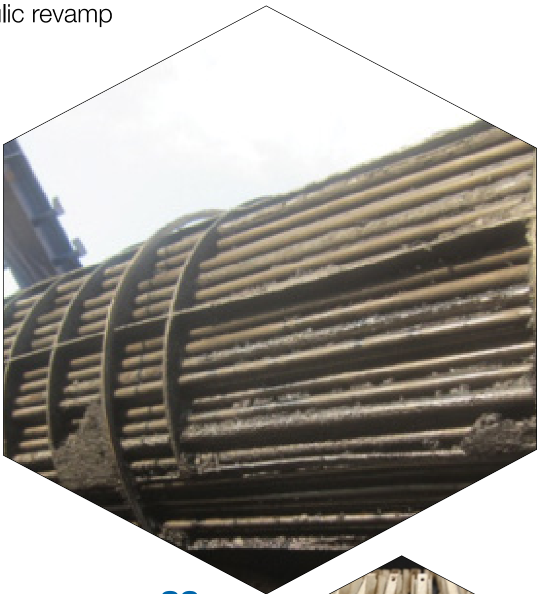
CHEMICAL ENGINEERING
ESSENTIALS FOR THE CPI PROFESSIONAL
www.chemengonline.com

December 2021 Volume 128 | no. 12

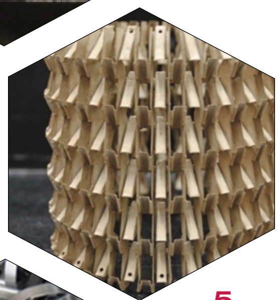
Cover Story

In the News

Technical and Practical

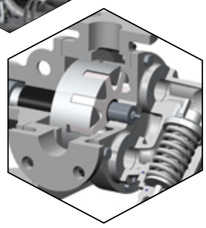


26



5

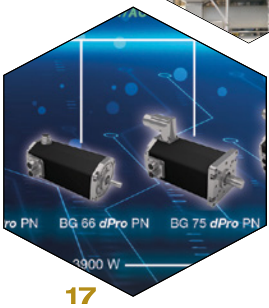
13



37

21

42



17

Equipment and Services

Departments

Advertisers

Chemical Connections

Follow @ChemEngMag on Twitter

Join the *Chemical Engineering* Magazine LinkedIn Group

Visit us on www.chemengonline.com for more articles, Latest News, New Products, Webinars, Test your Knowledge Quizzes, Bookshelf and more

For content related to COVID-19 and the CPI, visit www.chemengonline.com/covid-19/

Coming in January

Look for: **Feature Reports** on Data Utilization; and Process Safety; A **Focus** on Valves; A **Facts at your Fingertips** on Packaging; a **Newsfront** on Kirkpatrick Award Honorees; **New Products**; and much more

Cover design:
Tara Bekman

Editor's Page

Climate change on the world stage

At the time of this writing, COP26 is underway in Glasgow, Scotland. COP26 is the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change. Since the start of the first COP in 1995, climate change has evolved into a more urgent global priority. In 2015, a milestone was reached at COP21 when over 190 countries adopted the Paris Agreement and committed to lower greenhouse gas emissions in order to limit the rise in global temperatures to less than 2°C (with a target of 1.5°C), above pre-industrial temperatures. At that time, countries agreed to update their plans every five years — which, due to a pandemic delay, is this year.

And while progress has been made, according to the organizers of COP26, the world is currently not on track to meet the goals of the Paris Agreement, and much more must be done to avoid the continued escalation of catastrophic weather events.

Greenhouse gases

Greenhouse gases (GHG) are so-named because they trap heat in the earth's atmosphere. Of the four most-concerning ones — carbon dioxide, methane, nitrous oxide and fluorinated gases — focus has been given to reducing CO_2 and CH_4. According to the U.S. Environmental Protection Agency (EPA; www.epa.gov), CO_2 accounted for about 80% of all anthropogenic U.S. GHG emissions in 2019.

And while CH_4 emissions accounted for only 10% of those emissions, methane is more efficient at trapping radiation and is estimated to have about a 25 times higher impact than CO_2 on a weight basis over a 100-yr period. The Global Methane Pledge, first proposed in September and strengthened by an announcement of a global partnership at COP26, aims to reduce CH_4 emissions by 30% from 2020 levels by 2030. Over 100 countries have signed the pledge.

Technology advances

The chemical process industries (CPI) have been increasingly committed to ambitious climate-change goals. And with policies supporting such goals, more opportunities for technological advances are expected. Most recently, ExxonMobil stated that it plans to invest more than $15 billion over the next six years to lower GHG emissions. The company cites carbon capture and storage as a key technology to help reach net zero emissions goals by 2050. It also cites biofuels and hydrogen as areas with opportunities for significant emissions reductions.

And while many are working on an economical pathway to "green" hydrogen via electrolysis, advances to increase energy efficiency in the traditional steam-methane reforming process to reduce CO_2 emissions are also being pursued. Two such advances are detailed on p. 5 of this issue.

Countless activities supporting emissions reductions are underway in the scientific community. Challenges and advances in column use for carbon capture, for example, are outlined in our Newsfront on p. 13. A technique for combustion-free abatement of methane emissions was described in our November issue's Chementator section (p. 5).

As policies and company goals continue to point toward a sustainable future, innovation and sound engineering will help to make those goals a reality. We will continue to cover those advances in these pages, on our website and at our events. ■

Dorothy Lozowski, Editorial Director

Structured catalyst improves efficiency and hydrogen yields in SMR . . .

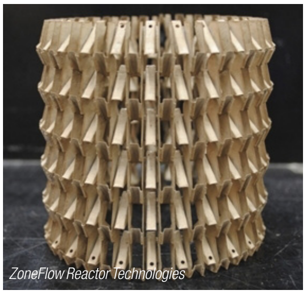
Commissioning has begun on a pilot plant designed to demonstrate the effectiveness of a structured catalyst module for steam-methane reforming (SMR) that solves the main heat-transfer inefficiencies associated with the conventional process. The structured catalyst technology improves the efficiency of SMR and increases the hydrogen produced.

Steam reforming of methane — an endothermic reaction typically carried out in multi-tube, fixed-bed reactors filled with catalyst-laden ceramic pellets — is subject to heat-transfer inefficiencies due to the size and random placement of the pellets.

"Heat transfer in SMR reactors depends in large measure on feed gas impinging the boundary layer of fluid at the tube wall," explains Bruce Boisture, president and co-founder of ZoneFlow Reactor Technologies, LLC (Windsor, Conn.; www.zoneflowtech.com), the developer of the new SMR technology. "But that heat-transfer mechanism is not optimized in the reactor tubes because of the random packing of the pellets in the reactor and their relatively large size (a concession to durability concerns) in relation to the diameter of the reactor tube. The result is a random gas-flow pattern within the reactor, sub-optimal heat transfer into the reactor and pressure drop across the reactor, and a significant amount of methane that can 'bypass' the catalyst along the tube walls. This high-temperature, but unreacted methane can cause coke buildup on the pellets."

The ZoneFlow structured catalyst (photo) features precisely engineered flow channels in its outer casing that are designed to force the methane to contact the tube wall while minimizing pressure drop. The geometry of its support structure keeps the catalyst-coated casing in continuous contact with the tube wall despite tube creep, eliminating bypass, Boisture comments. "In testing, heat-transfer efficiency was improved by 100% while maintaining the same pressure drop," Boisture says, which translates into an expected 15% higher throughput compared to conventional catalyst systems.

ZoneFlow's pilot plant, located at the Université Catholique de Louvain (Belgium), is undergoing final commissioning now, and the plant will start up by the end of 2021. Pilot testing results are expected in mid-2022. In early November, ZoneFlow announced a joint development agreement with Honeywell UOP (Des Plaines, Ill.; www.uop.com) to develop and commercialize the technology. Honeywell says the ZoneFlow reactor technology allows capital savings for new SMR plants and higher productivity for existing plants, and the opportunity to reduce steam requirements for SMR will reduce energy demand and CO_2 emissions.


ZoneFlow Reactor Technologies

Edited by:
Gerald Ondrey

FLOW BATTERY

Honeywell Inc. (Charlotte, N.C.; www.honeywell.com) introduced a new flow-battery technology that employs a proprietary electrolyte to provide reliable extended-duration energy storage — up to 12 h compared to lithium-ion batteries' (LIBs) 4 h. "The flow battery uses a non-flammable, water-based electrolyte and will not succumb to failure mechanisms like thermal runaway, unlike LIBs, which rely upon organic electrolytes," says Roopa Shortt, business development director, Honeywell Sustainable Technology Solutions.

The battery operates by reducing and oxidizing active species in the aqueous electrolyte upon charge and discharge of the battery. "We have developed ways to improve the speed and electrical efficiency of both charging and discharging to ensure stability across thousands of cycles. We have also optimized our design to take advantage of lower-cost materials

(Continues on p. 6)

. . . as does this new SMR technology

Meanwhile, a collaboration between Clariant Catalysts (Munich, Germany; www.clariant.com/catalysts) and Technip Energies N.V. (Zoetermeer, the Netherlands; www.technipenergies.com) has led to SMR technology that is said to achieve higher throughput and heat recovery in SMR. Technip Energies' Enhanced Annular Reforming Tube for Hydrogen (Earth) technology is designed as a drop-in solution, thus it is well suited to both existing and new reformer tubes. It is already in operation in the Akkim hydrogen (HyCO) plant in Turkey since January 2019, which shows excellent and stable performance, 20% less CO_2 emissions and nearly 40% lower fossil fuel consumption — all at equal H_2 and CO output, says Clariant. Clariant and Technip Energies have also been awarded two further contracts for Earth: a 21,000-Nm^3/h H_2 plant for Repsol, which will start up in February 2023 in Cartagena, Spain; and a second for an upgrade of an existing European H_2 plant.

Earth technology, developed and patented by Technip Energies, comprises a concentric tubular assembly in the SMR with a structured catalyst loaded in the outer annular space. The proprietary geometric layout, in combination with highly active, stable and mechanically robust catalyst — jointly developed by Clariant and Technip Energies — offers low pressure drop, maximum activity and heat transfer, despite the thermal and mechanical stress of the reforming process and the reduced volume of the Earth catalyst bed.

While traditional SMR technologies degrade high-grade process heat to generate high-pressure steam, Earth offers the possibility to utilize this heat to produce additional H_2 or to reduce the firing duty of the reformer, thus saving energy (and operating costs), according to Technip Energies. Steam export can be reduced by 50%, compared to conventional technology, the company says.

"[Earth] is a key technology of our BlueH2 by T.EN suite of solutions to achieve more sustainable hydrogen and syngas production the market has been seeking," says Stan Knez, chief technology officer at Technip Energies.

than are used in other batteries," adds Shortt. In 2022, Honeywell will deliver a 400-kWh unit to Duke Energy.

NAPHTHA CRACKER

In October, Coolbrook Oy (Helsinki, Finland; www.coolbrook.fi) and its partners started construction at Brightlands Chemelot Campus in Geleen, the Netherlands where the world's first electric steam cracker will be tested and further perfected towards commercialization. As part of the preparations for this pilot, air tests will take place in Finland before the end of this year with the patented Rotor Dynamic Reactor (RDR) technology (*Chem. Eng.*, May 2017, p. 9). The pilot at Brightlands Chemelot Campus will be fully operational in April 2022, after which the technology can be applied on a commercial scale in the near future.

Shell endorses the value of this technology by joining as an industry partner for the pilot project at Brightlands Chemelot Campus. In addition to providing up to 20% more ethylene yield than a traditional cracker, the Implementation of the RDR technology leads to a complete reduction in CO_2 emissions, 30% reduction in energy consumption and therefore 60% more profit, the company says. In July, the technology received over €5.5 million in subsidy from the Ministry of Economic Affairs and Climate Policy to enable this pilot to be carried out on an industrial scale.

NEW ALLOY

Sandvik Materials Technology AB (Sandviken, Sweden; www.materials.sandvik) recently received the first-ever contract from a renewable diesel plant for its Sanicro 28 high-alloy austenitic stainless steel. The reference order is for the use of Sanicro 28 in the reactor effluent-air coolers (REAC) of the hydroprocessing unit at one of the largest renewable diesel refineries in the U.S. Gulf Coast, due to start production in 2023.

Sanicro 28 is a multi-purpose austenitic stainless steel for service in extremely corrosive conditions. It was originally developed for the fertilizer in-

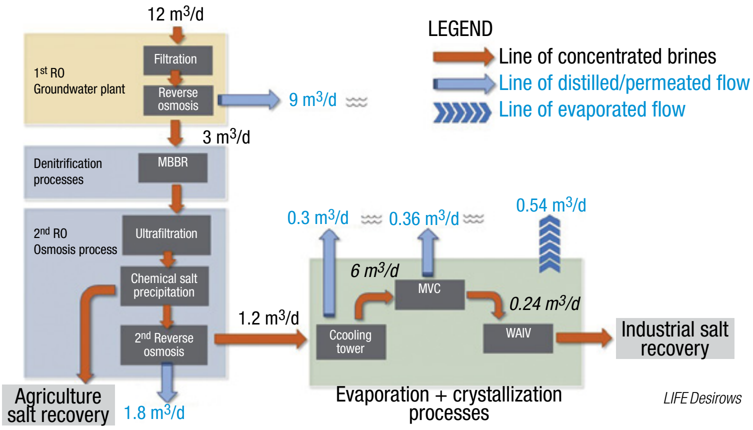
(Continues on p. 8)

Zero-liquid-discharge project to recover products from brine

HRS Heat Exchangers Ltd. (Watford, U.K.; www.hrs-heatexchangers.com) was recently awarded an order for the design, manufacture and installation of a mechanical vapor recompression (MVR) evaporation system for LIFE Desirows (lifedesirows.eu) — a three-year, €1.6-million project funded under the E.U.'s LIFE19 program. LIFE Desirows, which involves a consortium of companies and the Polytechnic University of Cartagena (UPCT; Spain; www.upct.es), aims to demonstrate a circular economy, zero-liquid discharge (ZLD) project to improve water quality in the Murcia region of Spain.

The consortium has developed a process (diagram) that removes nutrients and separates different salts from agricultural brine, so that they can be used as fertilizers. First, a double reverse-osmosis (RO) process generates a second brine, which then undergoes denitrification and chemical precipitation processes to remove the nutrients and the salts. The resulting solution is then thermally concentrated using a cooling tower and MVR to produce a saturated solution. Finally, the precipitated salts are removed from this saturated solution using wind-aided intensified evaporation (WAIE), providing a true zero-liquid discharge solution that converts the environmentally unfriendly brine into clean water for irrigation, fertilizer and salts for industrial use.

MVR evaporation is said to be one of the most economical ways of concentrating waste streams and does not require a thermal energy source. The electrical energy needed to drive the MVR compressor is supplied by photovoltaic solar panels. The evaporation module uses HRS corrugated-tube technology. The corrugated tubes generate extra product turbulence, which provides enhanced heat transfer and also delays heat exchanger fouling.



LIFE Desirows

New catalyst technology for MeOH synthesis boosts production and extends lifetimes

Newly launched catalyst technology, developed through a collaboration between Clariant (Muttenz, Switzerland; www.clariant.com) and Air Liquide Engineering & Construction (Frankfurt am Main, Germany; www.engineering-airliquide.com) and designed for methanol (MeOH) production, is capable of boosting cumulative MeOH yields by up to 15% and extending catalyst lifetimes by up to two years. Officially launched in October, the technology is known as MegaZonE, a play on the name of the Clariant catalyst material on which it based — MegaMax, a series of copper-oxide/zinc-oxide/alumina catalysts used for synthesizing MeOH from synthesis gas (CO and H_2).

Methanol synthesis typically occurs within a fixed-bed reactor, and MegaZonE uses several layers of catalyst material within the reactor that have differing activity levels. Because each catalyst layer is tailored to the specific reaction conditions along the reaction pathway, the layers optimize heat management and catalyst performance. As Clariant explains, catalysts with moderate activity are loaded in hotter zones of the converter to prevent hotspots, while activity-enhanced catalysts are placed further down the reaction pathway to intensify reaction rates in the lower portion of the converter.

"On the one hand, less thermal stress on catalysts will lead to longer catalyst lifetimes. On the other hand, high activity in the bottom part of the reactor will increase reaction rates and reduce byproduct formation by up to 10%," explains Stefan Heuser, senior vice president and general manager at Clariant Catalysts (Munich, Germany).

"MegaZonE is a game-changing technology that will increase customers' profits," says Heuser. "It enables more compact, resilient and longer-lasting designs, and is an example of Clariant's close collaboration with our partner Air Liquide Engineering and Construction," he adds.

MegaZonE was successfully applied to two world-scale methanol plants in Asia this year, and is showing excellent and stable performance, according to Heuser.

dustry and has been successfully used in the upstream oil-and-gas industry for many years. It offers excellent resistance to pitting corrosion and stress-corrosion cracking in high-chloride-bearing environments, making it an effective alternative to high-nickel alloys, such as alloy 825.

The alloy's breakthrough into renewable energy comes after two years of intense data generation that demonstrates Sanicro 28 also offers the corrosion and mechanical properties needed for the refining industry.

MECHANICAL ROUTE TO CLINKER

Portland cement — the binder used in concrete — contains ground cement clinker (calcium silicates and aluminates) that is produced by the high-temperature calcination of limestone and other components. This energy-intensive process generates one ton of CO_2 for every ton of cement produced. As a result, cement production is said to account for approximately 8% (or 2.7 billion ton/yr) of anthropogenic CO_2 emissions worldwide.

In a new study to find "greener" routes to cement production, chemists at the Johannes Gutenberg University Mainz (Germany; www.uni-mainz.de) have developed a method that produces cement clinker using ball mills at ambient temperature, instead of using calcination kilns operating at 1,000–1,500°C. Although the process is still in its infancy and limited to the laboratory scale, the method has the potential to drastically reduce CO_2 emission from cement production.

In the process, which is described in *Advanced Functional Materials* published last month, the raw lime ($CaCO_3$) is no longer converted into burnt lime in coal-fired kilns, but is simply milled with solid sodium silicate (Na_2SiO_3). This milling step produces an "activated" intermediate that contains the constituents of the cement in uniform distribution. When reacted with sodium hydroxide solution, a product is formed that is structurally similar to the calcium silicate hydrates. The formation of the cement paste and the setting with water proceed via a complex reaction cascade. The reaction mechanism for the multistep salt metathesis reaction were elucidated using x-ray and other analytical methods, in collaboration with researchers from the Gottfried Wilhelm Leibniz University (Hannover) and the Technical University of Darmstadt.

The researchers roughly estimate that the mechanical energy needed for the milling process (120 kWh/ton) is approximately 10% of the energy needed for the calcination process.

NEW YEAST

Novozymes North America Inc. (Franklinton, N.C.; www.novozymes.com) has recently introduced Innova Quantum, a new addition to its Innova yeast platform. With the new yeast, producers can increase ethanol yield by 2–3% compared to predecessor Innova

(Continues on p. 9)

Mining REEs from phosphogypsum . . .

Last month, the Pennsylvania State University (Penn State; University Park, Pa.; www.psu.edu), Case Western Reserve University (Cleveland Ohio; www.case.edu) and Clemson University (S.C.; www.clemson.edu) received a $1.7-million National Science Foundation grant for a four-year project to recover rare earth elements (REEs) from phosphogypsum.

Phosphogypsum is formed when phosphate rock is processed into fertilizer, and contains small amounts of naturally occurring radioactive elements, such as uranium and thorium. Because of this radioactivity, the byproduct is stored indefinitely, and improper storage can contaminate soil, water and the atmosphere. "Today, an estimated 200,000 tons of rare earth elements are trapped in unprocessed phosphogypsum waste in Florida alone," according to Lauren Greenlee, associate professor of chemical engineering and leader of the Penn State effort along with co-principal investigator Rui Shi, assistant professor of chemical engineering. "This source of rare earth elements is presently untapped due to challenges associated with radioactive species and the difficulty of separating the individual elements," she says. "The vision for this project is to discover new separation mechanisms, materials and processes to recover valuable resources, including rare earth elements, fertilizers and clean water, from waste streams of the fertilizer industry, paving the way for a sustainable domestic supply of rare earth elements and a sustainable agriculture sector."

To harvest the REEs trapped in phosphogypsum, the researchers propose a multistage process using engineered peptides capable of precisely identifying and separating out the rare earth elements through a specialized membrane. "Individual rare earth elements have similar sizes and identical formal charges, so traditional membrane separation mechanisms are insufficient," Greenlee says. "A key technical goal of this research is to discover the mechanisms that underpin peptide-ion selectivity and leverage those mechanisms to design a new class of highly selective membranes." Researchers from Case Western will develop the engineered peptides, guided by computational modeling work performed at Clemson.

The proposed project will also complement other Penn State research, including work using naturally occurring protein molecules to extract grouped rare earth elements from other industrial waste sources (see next story).

. . . and from unconventional sources

In October, researchers from Penn State and the Lawrence Livermore National Laboratory (LLNL; Calif.; www.llnl.gov) described — in an article published in *ACS Central Science* — a new method that improves the extraction and separation of rare earth elements (REEs) from unconventional sources, including industrial waste, such as mine tailings and electronic waste. "In this study, we demonstrate a promising new method using a natural protein that could be scaled up to extract and separate rare earth elements from low-grade sources, including industrial wastes," according to Joseph Cotruvo Jr., assistant professor and Louis Martarano Career Development Professor of Chemistry at Penn State, a member of Penn State's Center for Critical Minerals, and co-corresponding author of the study.

The new method takes advantage of a bacterial protein called lanmodulin (LanM), previously discovered by the research team, that is almost a billion times better at binding to REEs than to other metals. The protein is first immobilized onto tiny beads within a column to which the liquid source material is added. The protein then binds to the REEs in the sample, which allows only the rare earths to be retained in the column and the remaining liquid drained off. Then, by changing the conditions (for example, by changing the pH or adding additional ingredients), the metals can be released from the protein for recovery. By carefully changing the conditions in sequence, REEs could be selectively separated.

The researchers first demonstrated that the method is "exceptionally good" at separating the REEs from other metals. They were also able to separate yttrium from neodymium — both abundant in primary rare-earth deposits and coal byproducts — with greater than 99% purity; and neodymium from dysprosium with greater than 99.9% purity in just one or two cycles, depending on the initial metal composition.

Waste-based ceramics improve energy-storage economics

Ceramic materials' high heat resistance makes them a promising media for thermal energy storage, but their high costs have inhibited their widespread use for this application. Now, a new technology offered by Seramic Materials Ltd. (Masdar City, U.A.E.; www.seramic.eco) can efficiently convert a wide range of industrial solid waste materials, such as steel slag and incinerator ash, into ceramic products used for energy storage and construction. "On average, our products are up to 50% cheaper than conventional ceramics, and the carbon footprint can be reduced by up to 60% when compared to materials like alumina, which require energy-intensive extraction and transport of bauxite raw materials. We replace those with locally generated wastes that are always available," says Nicolas Calvet, CEO of Seramic Materials.

The key to Seramic Materials' technology is a patented method of mixing different waste streams and fine-tuning process characteristics to yield a specific end-product formulation. "There is great variability in the waste composition, based on industrial source and geography, meaning that we have to readjust our process and formulation and tune the firing temperature before launching production," explains Calvet. These proprietary analyses take place in Seramic Materials' dedicated laboratory, where characteristics such as water absorption and compression resistance are precisely tuned to optimize product formulation. Since the main production process uses conventional equipment, Seramic Materials is partnering with existing ceramics factories to utilize their facilities during periods of inactivity, which significantly lowers capital expenditures.

The company has recently commercialized a technical ceramic product called ReThink Seramic — Flora, which can reach temperatures as high as 1,250°C, making it ideal for use in concentrated solar-power (CSP) installations. Seramic Materials has manufactured 30 tons of Flora at a plant in Europe, and projects deploying the material are in development in Spain and the U.S. Work is also underway for a workshop in Abu Dhabi to produce 20,000 m^2/yr of sustainable architectural tiles.

Force. For a 100-million-gal/yr plant, this translates to an additional $1–2 million in revenue, says Novozymes. Designed to operate in fermentations >60 h, Quantum with new strain development is capable of converting the most sugar to ethanol while significantly lowering fermentation by-products such as glycerol up to 40% — all without the trade-off and risk of robustness loss experienced with competing yeasts. And, Quantum expands plant flexibility by fermenting to ethanol concentrations of more than 16% w/v, while eliminating the need for expensive nutritional supplements, says Novozyme.

PHOTOSENSITIZER

Researchers from the Tokyo Institute of Technology (Tokyo Tech;

(Continues on p. 10)

Japan; www.titech.ac.jp) have developed a new osmium complex that can absorb the entire wavelength range of the visible spectrum. When combined with a ruthenium (II) catalyst, the complex enables the direct reduction of CO_2 into formic acid.

Although Ru complexes are commonly used redox photosensitizers, they do not absorb visible light, whereas alternative panchromatic complexes cannot also be used for photoredox reactions because the lifetimes of their excited states are too short. The Tokyo Tech combination, described in a recent issue of *Chemical Science*, overcomes both hurdles. The osmium complex absorbs all wavelengths in the visible spectrum, and the excited state has a sufficiently long lifetime (40 ns) for initiating electron-transfer processes required for reduction.

When irradiating the combination with 770-nm light, the system photocatalytically reduced CO_2 into formic acid with good reaction turnover numbers. ❐

A new spin on ultrasonic algae control in wastewater-treatment applications

Ultrasound treatment is a non-chemical method to control algae using specific sound frequencies emitted through water to cause internal damage to polluting algae cells. Most previous work in the area of ultrasonic algae control has focused on very loud emitted frequencies to create cavitation bubbles that damage the algae cells, but a new line of products from Sonic Solutions Algae Control LLC (Northampton, Mass.; www.sonicsolutionsllc.com) and WaterIQ Technologies (Wilson, Wyo.; www.wateriqtech.com) emits over 2,000 different frequencies on two bandwidths to take advantage of critical structural resonance (CSR), the specific frequency that ruptures the vesicles within algae cell walls. The damaged algae cells lose their buoyancy or have torn inner cell walls, causing them to naturally decompose due to lack of sunlight or damaged functions. Launched in October at Weftec, The Pulsar 4000 and 3000 models are said to be the only devices on the market to provide 360-deg, CSR-based ultrasonic coverage in ponds, reservoirs and clarifier tanks.

"When you emit frequencies at an object's CSR, the object begins to vibrate, and if the frequency is strong enough, the object can damage itself with shearing vibration," explains George Hutchinson, chief technology officer and vice president of operations at Sonic Solutions Algae Control. A benefit of CSR-based control over cavitation is lower power consumption and longer distance coverage. "To use cavitation to damage algae several hundred meters away, the device has to create almost an explosive surge to create cavitation at that distance. Our devices stay well below the cavitation threshold," says Hutchinson.

Furthermore, the wide range of frequencies emitted by the devices enable them to mitigate over 90% of different algae species encountered in wastewater treatment plants, agricultural farms and more. The key to tapping into so many frequencies is a specially designed piezo transducer head and microprocessor. ■

Business News

Plant Watch

Chemours to open new HFO plant in Arkansas

November 11, 2021 — The Chemours Co. (Wilmington, Del.; www.chemours.com) announced plans to open a new facility located in El Dorado, Ark. The new plant will be dedicated to Chemours' Opteon1150 hydrofluoroolefin (HFO), chemically referred to as HFO-1336mzzE.

ALPLA starts up HDPE recycling plant in Mexico

November 11, 2021 — ALPLA Group (Hard, Austria; www.alpla.com) has opened a new recycling plant for high-density polyethylene (HDPE) plastic in Toluca, Mexico. The facility is currently designed for a capacity of 15,000 metric tons per year (m.t./yr) of recycled HDPE (rHDPE) in pellet form, and the company has announced plans to double the annual regrind production capacity to 30,000 m.t./yr in the second half of 2022. The investment in the new plant was around €20 million.

Honeywell commercializes new recycling technology, will build plant in Spain

November 3, 2021 — Honeywell International Inc. (Charlotte, N.C.; www.honeywell.com) has launched a new chemical recycling technology for plastic waste, and will commercialize this technology at a new plant in Spain. Honeywell and engineering firm Sacyr S.A. (Madrid, Spain; www.sacyr.com) will jointly co-own and operate the facility in Andalucía with a capacity to transform 30,000 m.t./yr of mixed waste plastics into recycled polymer feedstock. Production is expected to begin in 2023.

Nouryon to increase colloidal silica manufacturing plant in Wisconsin

November 2, 2021 — Nouryon (Amsterdam, the Netherlands; www.nouryon.com) plans to expand production capacity at its Levasil colloidal-silica manufacturing facility in Green Bay, Wis. to meet increasing demand from the construction and packaging markets. Construction of the facility expansion is planned to be finalized in the second half of 2022.

Elkem to expand specialty-silicone production plant in France

October 27, 2021 — Elkem ASA (Oslo, Norway; www.elkem.com) will invest around €36 million to upgrade and debottleneck its specialty-silicone upstream plant in Roussillon, France, resulting in a 20,000-m.t./yr capacity expansion. This brings the site's capacity to 100,000 m.t./yr of effective silicone intermediates for end uses including semiconductors, 3D printing and medical devices. The expansion is anticipated to come online during the third quarter of 2023.

Evonik expands specialty silica production in Japan

October 25, 2021 — DSL Japan, a joint venture of Evonik Industries AG (Essen, Germany; www.evonik.com) and Japanese pharmaceutical firm Shionogi, has opened a new production line for specialty silicas at the company's site in Ako, Japan. The new capacities expand the overall production capacity of custom silica solutions by 30%.

ADM and Gevo join forces to produce renewable fuels in the U.S.

October 28, 2021 — Archer-Daniels-Midland Co. (ADM; Chicago; www.adm.com) and Gevo, Inc. (Englewood, Colo.; www.gevo.com) have signed a memorandum of understanding (MoU) to support the production of both ethanol and isobutanol that would then be transformed into renewable hydrocarbons, including sustainable aviation fuel (SAF), using Gevo's processing technology and capabilities. About 900 million gal of ethanol produced at ADM's facilities in Columbus, Neb., Cedar Rapids, Iowa and Decatur, Ill., are expected to be processed utilizing Gevo technology, resulting in production of approximately 500 million gal of renewable hydrocarbons.

Albemarle to build two new lithium-conversion plants in China

October 22, 2021 — Albemarle Corp. (Charlotte, N.C.; www.albemarle.com) has signed agreements to move forward with its design, engineering and permitting plans to expand lithium-conversion capacity at the Yangtze River International Chemical Industrial Park in the Zhangjiagang Free Trade Zone (Jiangsu province) and the Pengshan Economic Development Park in the Pengshan District (Sichuan province). Albemarle will build a conversion plant at both sites, each of which has planned production capacity initially targeting 50,000 m.t./yr of lithium hydroxide. It is expected that these plants would start construction during 2022 and complete construction by the end of 2024.

Mergers & Acquisitions

Sika to acquire MBCC Group for €5.2 billion

November 11, 2021 — Sika AG (Baar, Switzerland; www.sika.com) has signed a definitive agreement to acquire MBCC Group (Mannheim, Germany; www.mbcc-group.com), the former BASF Construction Chemicals business, from a global private equity firm, for a consideration of €5.2 billion ($5.96 billion). MBCC Group is active in the field of construction systems and admixture systems and has more than 130 production facilities in over 60 countries.

LINEUP

ADM
ALBEMARLE
ALPLA
BASF
CHEMOURS
DUPONT
EASTMAN
ECOLAB
ELKEM
ENTEGRIS
EVONIK
FLINT HILLS RESOURCES
GEVO
HONEYWELL
INVISTA
LANXESS
MBCC GROUP
NOURYON
SIKA
SYNTHOMER

Look for more latest news on chemengonline.com

Lanxess to separate High Performance Materials business

November 11, 2021 — Lanxess AG (Cologne, Germany; www.lanxess.com) will transfer its High Performance Materials (HPM) business unit to an independent legal corporate structure. With 14 sites worldwide, HPM is a supplier of high-performance plastics that are used primarily in the automotive, electrical and electronics industries.

Flint Hills Resources transfers its propylene business to Invista

November 9, 2021 — Flint Hills Resources, LLC (Wichita, Kan.; www.fhr.com) will transfer its propylene business to Invista (Wichita, Kan.; www.invista.com). The move includes Flint Hills Resources' chemical facilities in Houston and Longview, Tex.

DuPont to acquire Rogers Corp. for $5.2 billion

November 2, 2021 — DuPont (Wilmington, Del.; www.dupont.com) has entered into a definitive agreement to acquire Rogers Corp. (Chandler, Ariz.; www.rogerscorp.com) for $5.2 billion. Rogers specializes in engineered materials, including high-frequency circuit materials, ceramic substrates and high-performance foams. The transaction is expected to close in the second quarter of 2022. Rogers operates a global network of 14 manufacturing sites in North America, Europe and Asia. DuPont also plans to divest a significant portion of assets from its Mobility & Materials division.

Ecolab to acquire ion-exchange resin manufacturer Purolite

October 29, 2021 — Ecolab Inc. (St. Paul, Minn.; www.ecolab.com) will acquire Purolite (King of Prussia, Pa.; www.purolite.com), a provider of ion-exchange resins for separation and purification applications in many industrial sectors, including life sciences, microelectronics, nuclear power and food and beverage. The acquisition is valued at approximately $3.7 billion.

Eastman to sell adhesives resins business to Synthomer

October 28, 2021 — Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com) entered into a definitive agreement to sell its adhesives resins assets and business to Synthomer Plc (London, U.K.; www.synthomer.com). The $1-billion sale consists of several product lines, including: hydrocarbon resins, pure monomer resins, polyolefin polymers, rosins and dispersions and oleochemical and fatty-acid resins. The business is currently part of Eastman's Additives & Functional Products segment.

BASF to sell Precision Microchemicals business

October 27, 2021 — Entegris, Inc. (Billerica, Mass.; www.entegris.com) and BASF SE (Ludwigshafen, Germany; www.basf.com) have signed an agreement for the sale of BASF's Precision Microchemicals business to Entegris for $90 million. The Precision Microchemicals business is part of BASF's Coatings division, operating under the Chemetall brand. It focuses on high-purity materials, including cleaning chemistries and chemical mechanical planarization slurries used in machining and surface conditioning. ■

Mary Page Bailey

Taking a Holistic Approach to Column Internals

Combining new and improved high-performance column internals and a whole-system view provides a comprehensive solution with more benefits

Today's economic and environmental pressures have chemical processors looking into projects that will help them achieve more throughput from existing columns while also reducing energy use. New high-performance trays and packings can certainly help increase capacity and efficiency of the tower. However, it is a holistic approach to the system and all the internals that yields the greatest benefits.

"Processors are always trying to maximize utilization of their assets, meaning they want to get maximum throughput while maintaining or improving product quality and also being cognizant of their carbon footprint, making energy utilization of the column very important," says Izak Nieuwoudt, chief technology advisor with Koch Engineered Solutions (Wichita, Kan.; www.kochind.com). "It may seem like looking for the Holy Grail, but it is possible to achieve."

For this reason, continues Nieuwoudt, there is a constant drive to improve column internals, leading to some significant improvements in trays and packings, but also to other column internals, as well. "For instance, a high-performance packing might yield even better results if it is paired with improved liquid distributors," he says.

Babak Rafienia, mass-transfer technology manager with Amacs (Houston; www.amacs.com) asserts: "Looking at a tray or packing alone isn't the only way to find better throughput and efficiency. We have seen many applications that need higher throughput and, while replacing conventional trays and packings with high-performance components can help, better results are always achieved when you look at the complete system, Often, we find other considerations, like inlet piping or feed arrangement, can affect the performance of the tower, so it should be looked at as a system to provide a comprehensive solution with a holistic approach."

High-performing trays/packings

If a tower is underperforming due to the use of conventional trays and packings or if a processor wants to improve capacity or efficiency of existing equipment, a move to high-performance trays and packings can indeed enhance performance.

"In the recent economy, we have seen a lot of projects put on hold due to capital, logistical and material issues, and processors are trying to get more capacity and higher efficiencies from existing columns," says Moize Turkey, technology director with Amacs. "In these cases, high-performance internals can boost the performance."

For instance, the most recent generation of Amacs' Superblend ASB high performance random packing (Figure 1) provides superior performance when compared to previous packing generations in terms of both capacity and efficiency. Likewise, SEMV mini-valve trays are high-performance internals that can improve both capacity and efficiency by breaking vapor jets and providing better vapor-liquid contact, says Rafienia.

FIGURE 1. Amacs' fourth-generation high-performance Superblend ABS packing is a combination of various packing sizes, which provides the efficiency of the smaller and the capacity of the larger packing to provide enhanced benefits

Koch's Nieuwoudt adds that the drive to increase column performance has led to improvements in trays and packings that allow increases to both capacity and efficiency in existing columns. For example, the company's new Flexipro valve trays offer improved capacity and efficiency, enhanced push and sweeping of the tray deck, which leads to improved fouling resistance and higher turndown ratio with no increase in pressure drop. This situation opens opportunities for revamps and new vessels. The valve trays extend the operating range of fixed valves to levels close to those of movable valves, while maintaining the performance and reliability of fixed valves.

Mark Pilling, manager of technology with Sulzer Chemtech USA (Tulsa, Okla.; www.sulzer.com), agrees that newer technologies can help achieve both capacity and efficiency improvements. "Our UFM valve trays offer a robust design that works over a variety of operating conditions and consistently provides high efficiency. They were designed using computational fluid dynamics (CFD) to ensure ideal mixing between the vapor and liquid on the tray deck to maximize efficiency while simultaneously increasing capacity," he says (Figure 2).

Taking a holistic approach

Often, the problem with underperforming columns is that existing towers are being pushed too far, which

FIGURE 2. Sulzer's UFM valve trays were designed using computational fluid dynamics to ensure mixing between the vapor and liquid on the tray deck in order to maximize efficiency while simultaneously increasing capacity

may necessitate a revamp of more than just trays and packings, says Andreas Danninger, head of sales engineering with Raschig GmbH (Ludwigshafen, Germany; www.raschig.com). "If the tower was designed and built for certain operating conditions that have since been gradually changed, the tower may not perform well, because the internals are not suitable for the current operating conditions," he says.

"The problems can be manifold," he continues. "From liquid distributors not being able to handle increased liquid loads to the gas distribution setup not being suitable for changed gas-feed flows, to random and structured packings operating close to flooding conditions to mass transfer trays not being able to handle current operating conditions. Addressing these issues not only requires modern high-performance equipment, but also a sophisticated engineering approach."

Danninger says the first option that comes to mind is replacing conventional packing types with a modern, high-performance random packing, such as the Raschig Super-Ring PLUS, which provides increased throughput capacity, efficiency, pressure drop and fouling resistance (Figure 3). "But it is not only the packing that affects column performance. If internals like gas and liquid distributors are not suitable for the actual operating conditions, then the packing can't reach its full potential," he says. "A redesign of the internals, optimized for the actual process conditions, can significantly enhance packing performance."

The same, he says, applies to trays where replacement with a high-capacity tray can enhance throughput capacity. For example, the Raschig R-MV provides higher capacity and lower pressure drop per theoretical stage compared to conventional valve trays due to the unique crowned head of the valve, which promotes improved lateral vapor release, reducing froth height and entrainment and increases hydraulic capacity. "However, a careful redesign of the existing trays with optimizations to the downcomer sections of the active panes for the actual operating conditions can further enhance performance and operability of the tower."

Similarly, Christian Geipel, managing director with RVT Process Equipment GmbH (RVT; Steinwiesen, Germany; www.rvtpe.com), says that there is a growing need for tailor-made solutions in revamps of existing plants that need modifications to fulfill new demands or achieve longer, more predictable run times in fouling applications, higher capacities and lower pressure drop, wider operating ranges for more flexibility or better energy efficiencies. These can be achieved by combining high-performance trays or packings with other modern internals.

USING COLUMNS FOR CARBON CAPTURE

One of the latest trends is using columns for carbon capture applications. While the technology is not new, the "parasitic" energy demand and the enormous column sizes required for the application necessitate a lot of research and optimization before use becomes widespread, says Koch's Nieuwoudt.

"There has been a lot of activity on the carbon capture front, but there is still a lot of exploratory work to be done before we see a flood of large industrial applications due to the high cost and the required size of the installations," notes Nieuwoudt. "When you look at the size of the units being proposed, they are humongous. Some of the proposed processes would use scaled-up conventional internals and others would be completely different because some proposed carbon capture columns are rectangular vessels of about 60 by 80 ft.

"This presents mechanical challenges around the mass-transfer internals that have to be solved before widespread use," he continues. "The industry is spending time working on proper packings and mechanical solutions for supporting those packings, as well as what the liquid distributor details would look like in a 60-by-80-ft vessel."

Sulzer Chemtech's Pilling adds: "On columns of this scale, issues such as the thermal expansion factors of dissimilar metals can cause problems. Also, there are massive flows coming in, so there are typically multiple feed nozzles at a given column elevation. This requires a lot of time spent with computational fluid dynamics to be sure the vapor flow goes into the column correctly. There are also issues with liquid distributors that must be flow tested, but the distributors are so massive that they are often bigger than the test facility itself."

Despite these and other issues, Sulzer Chemtech has successfully installed carbon capture columns in power plant applications, where during the process of burning fossil fuels, CO_2 emissions emerge. In these applications, after the fossil fuels have been burned, the off-gas stream feeds into the absorption column. In the column, the amine solutions come into contact with the gas stream and absorb CO_2. The larger the contact area, the more CO_2 is removed from the gas. The specialized design of effective structured packings, such as Sulzer's MelllapakCC, creates large surface areas of contact for the gas and liquid, enhancing the absorption. The process results in a nearly CO_2-free gas stream and in amine solutions rich in CO_2. MellapakCC packing is again used to treat the amine solution so the CO_2 is removed for storage and the amine liquid is recycled and reused in the process.

While these columns are normally very large and use a lot of energy, these application-specific internals help reduce column size, saving on materials, space and capital and energy costs. ❐

FIGURE 3. The Raschig Super-Ring PLUS provides increased throughput capacity, efficiency, pressure drop and fouling resistance

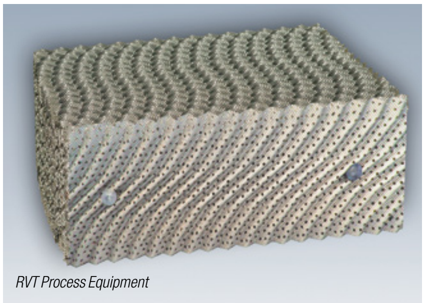


FIGURE 4. RVT has developed a novel high-capacity structured packing, the SP-Line, which offers modified channel geometry to provide low pressure drops and higher capacity

"In terms of energy efficiency, which for mass-transfer equipment mainly corresponds to pressure drop, a revamp from trays or random packings to structured packings is often a solution," says Geipel. RVT has developed a novel high-capacity structured packing, the SP-Line, which offers modified channel geometry to provide low pressure drops and higher capacity (Figure 4). "However, especially for very low liquid loads, these packings can be combined with other internals such as modern liquid distributors. An improved spray nozzle distributor that combines spray nozzles with splash plates was developed and has been successfully used in refinery vacuum columns where it reduces entrainment and fouling in the packing sections above the distributor without sacrificing liquid distribution quality to the packing section below."

Brad Fleming, manager of Sulzer GTC's proprietary equipment technology group (Houston; www.gtctech.com), says looking at the system holistically can provide benefits outside the column, as well. "High-performance internals can be tailored to achieve many process objectives," he says. "For instance, in some processes, reducing pressure drop through the column can have benefits on downstream units. If the overhead gas leaving a main fractionator is going to a compression stage, by reducing pressure drop of the fractionator, you can increase the suction pressure to the compressor and that reduces the power requirement of the compressors or increases its throughput capacity. You can use the characteristics of the column to yield collateral benefits to other pieces of equipment."

Fleming continues: "Most processors realize that you can replace standard valve trays and get a 20 to 30% increase in throughput, but if you really understand the process, you can use the benefits to optimize further. This means you can use the same number of trays in a column and achieve better product purity, while at the same time, those improvements in efficiency can be translated into energy reductions because you don't have to drive the column as hard, so the real benefits come from how you use the improvements in equipment technology to drive a desired, optimized result throughout the process."

Rainald Pabst, sales product manager for columns and internals with DeDietrich Process Systems GmbH

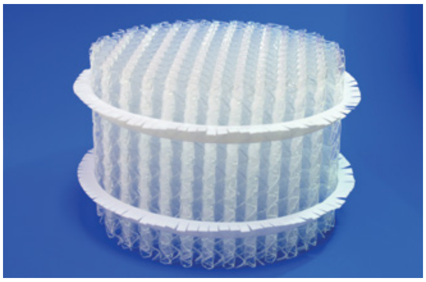


FIGURE 5. DeDietrich's Durapack structured mass-transfer packing offers a higher number of separation stages, better wettability and mechanical stability and glass grids with a larger free cross-area

(Mainz, Germany; www.dedietrich.com), agrees that overall optimization comes from considering the process as a whole. "No two columns are alike. In each individual case it is important to analyze the situation precisely to determine the optimum solution for the separation process and the column."

He points to a revamp of a nitric acid concentration column using modern DeDietrich internals. "The column was originally equipped with cast iron internals, which caused many problems during operation of the plant, including limited load range, permanent blocking of the distributor holes due to breakage of the random packing and risk of fracture due to thermal stress. As a result, the required throughput of the column could not be achieved so the plant produced about 20% less than originally planned and the column required intensive maintenance," he says.

DeDietrich remedied the situation by installing new equipment. In addition to its Durapack structured mass transfer packing (Figure 5), which offers a higher number of separation stages, better wettability and mechanical stability and glass grids with a larger free cross-area, Coretray distribution trays and SiC-channel distributors were installed. "The Coretray distributor trays combine the functions of collection, distribution and support in a single component," he says. "The possible load range is designed individually and is enormous. Thus, lower loads can be handled without loss of distribution quality. Hydraulic overloads up to 280% can be handled without any problem, which is helpful for heavily polluting or foaming media. Further, the SiC-channel distributor is characterized by very good distribution quality.

"These improvements allowed the processor to increase performance up to 120% of the original required capacity," he says.

To enable examining systems as a whole, Koch recently launched a software package, TowerView, that performs real-time calculations of the performance and health of equipment inside distillation or absorption towers. "The software takes advantage of the ability to digitalize separation equipment and provides real-time feedback on the values that cannot be measured," says Nieuwoudt. "Often processors run a distillation column and measure pressure drop, temperature and composition of streams using probes in the column, but these values can't provide information about issues such as whether certain parts of the trays are close to flooding."

"Our calculation methodology provides users with a real-time view of what things look like inside the column to give a proactive view of where the tower is relative to its limitations," he says.

The software can be used online in real time to provide alerts when there are potential problems, or offline to run what-if scenarios that can be used to enhance performance of the column before making physical changes.

According to the experts, looking at problems or enhancing performance of the column should change from focusing on a single point or component and move toward looking at it as a whole package. Often tweaking and finding small optimizations within the entire system can help operators improve the throughput or performance, which isn't always specific to just one internal. A solution-driven strategy that examines the entire picture should be the focus of optimization projects. ■

Joy LePree

Focus on Motors and Drives

A new coupling increases performance of predecessor

Late last year, this company introduced a new type in its N-Eupex coupling series, while increasing the performance and bore capacity of the entire series. The new double-cardanic N-Eupex DK (photo) connects the shaft ends of the drive and driven machine via two elastomer joints instead of only one joint, as is the case with other coupling types. The introduction of the second elastomer joint increases the damping properties of the coupling and results in a lower torsional stiffness. This reduces vibrations, and the adjacent machine components are less stressed. In addition, the possible radial offset is increased more than fourfold. At the same time, this company increased the performance of the entire N-Eupex series by approximately 30%, and the bore capacity by up to 25%. Users benefit from higher torque, increased rotation speed and a change in size. — *Flender GmbH, Bocholt, Germany*
www.flender.com

These motors now have integrated ProfiNet interface

This company was said to be the first to completely integrate ProfiNet functionality, including the PROFIdrive profile with application classes 1 and 4, into motors as standard. This offers ProfiNet users significant advantages in cabling, commissioning and operation. Only the power supply and bus connection need to be established, and the motor can be integrated into the commissioning environment, for example, the TIA Portal, and programming can begin. During operation, the controller accesses all motor parameters and uses them for process control, error monitoring, predictive maintenance and many other IIoT or cloud features. BG 95 dPro PN (photo) was the first fully integrated ProfiNet motor from this company. — *Dunkermotoren GmbH, Bonndorf/ Schwarzwald, Germany*
www.dunkermotoren.de

Users can operate this speed starter intuitively

The safe, simple and efficient operation of three-phase asynchronous motors is an important objective in a large number of applications. The Contactron Speed Starter (photo) is a new device class that bridges the gap between motor starters and frequency converters with easy operation. The operator interface consists of a rotary switch and three buttons with a display, allowing users to make all settings intuitively. This compact and cost-effective solution provides all of the functions necessary for different speeds. These include normal speed, creeping speed, soft start, energy efficiency and ramp functions, and even safe stopping with the Safe Torque Off function. — *Phoenix Contact GmbH & Co. KG, Blomberg, Germany*
www.phoenixcontact.com

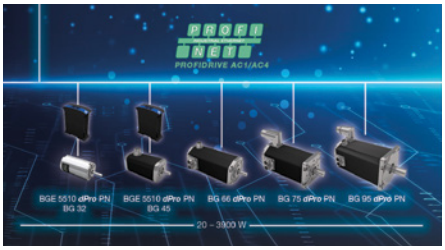
These motor breaks are available when you need them

This company has introduced a quickship program for MagnaShear motor brakes (photo), with parts ready for assembly in as little as a day. Brakeless brake motors from ¾ to 5 hp are also in stock, so that assembled brake motors can be delivered quickly, eliminating supply chain concerns, and the need to use inferior dry friction-braking systems. MagnaShear motor brake assemblies feature oil shear technology, so they do not require regular maintenance or adjustment. With quiet, smooth operation and high accuracy and repeatability, they provide a long service life (typically 5 to 10 times that of dry friction brakes), says the company. — *Force Control Industries, Fairfield, Ohio*
www.forcecontrol.com

New coating enables boost in efficiency of electric motors

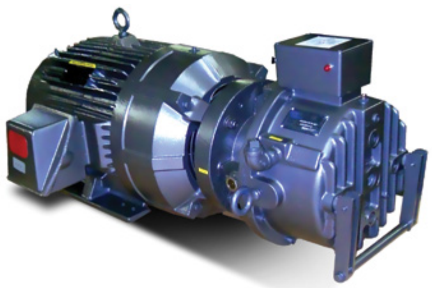
Electric motors have laminated cores that are made up of thin laminations of electrical steel. These laminations are coated on both sides to insulate them, which reduces magnetic losses. The coatings must also be heat resistant. Beckry Core is a waterborne coreplate varnish (CPV) that not only al-

Flender



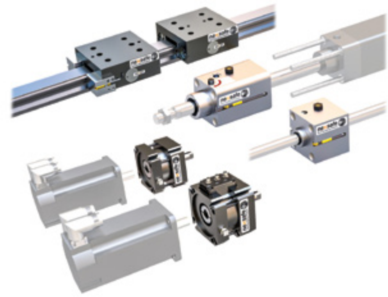
Dunkermotoren

Phoenix Contact

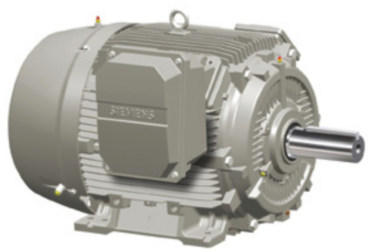


Force Control Industries

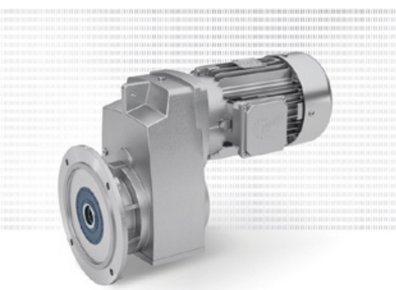
Beckers Group



Nexen Group



Siemens



NORD Gear

Rockwell Automation

lows thinner coating than other products on the market, but also enhances electrical motor efficiency by reducing power losses in the core laminates (photo) and improving magnetic properties, says the company. — *Beckers Group, Berlin, Germany*
www.beckers-group.com

Certified functional safety products introduced

Launched in April, this company's Certified Safety Products (photo) provide machine builders with a verified and reliable solution to increase the safety of processes and machines. The rail brakes, servomotor brakes and rod locks (photo) are said to be the first in North America to earn the Intertek Functional Safety (FS) Mark. They are certified to comply with ISO 13849-1, Categories B through 4 and Performance Levels PLa through PLe. With spring-engaged, air-released functionality, these products are default to lock, making them ideal for emergency stopping and holding applications. The rail brakes, servomotor brakes and rod locks can be mounted to servo motors, linear devices, pneumatic cylinders, round rails, linear rods, round shafts and linear guide systems. — *Nexen Group, Inc., Vadnais Heights, Minn.*
www.nexengroup.com

Motors meet or exceed NEMA Premium efficiency standards

The Simotics SD200 severe-duty motor in frame size 440 (photo) is the latest offering in the low-voltage Simotics motor family. Providing high productivity and energy-efficient operation in all torque ranges, these new cast-iron NEMA motors are built to power pumps, fans, compressors, hoists, winders and similar equipment in harsh environments. The SD200 motors offer 75–800-hp output and feature 444-5013 cast-iron frames for operation in 460- and 575-V ranges. They meet or exceed NEMA Premium MG1 Table 12-12 efficiencies. A wide selection of options is offered, including IP56 ingress protection, encoders, brakes and blowers, plus others to suit the application. They are designed for use in the harsh environments of oil-and-gas, petrochemical, grain and rock productuction, plus food-and-beverage and other sectors with Div. II, Class 1 and 2 conditions. — *Siemens Corp., Chicago, Ill.*
usa.siemens.com

Shaft gear units provide more power, flexibility and reliability

This company's redesigned line of small Clincher parallel gear units (photo) delivers increased power and torque capacity for a variety of applications. These re-engineered versions are lightweight, have improved heat dissipation, are more cost-effective and are available with this company's nsd tupH sealed-surface conversion for wash-down and extreme environments. When combined with variable frequency drives, Clincher units provide efficiency and economy for a wide range of systems. Two mounting configurations are possible: a B14 face flange/foot mounted version and a B5 flange version. — *NORD Gear Corp., Waunakee, Wis*.
www.nord.com

Improved performance for medium-voltage drives

Earlier this year, this company introduced multiple enhancements to the Allen-Bradley PowerFlex 6000T medium-voltage drives (photo). The drives now include TotalFORCE technology, which provides precise control of speed and torque, diagnostic information for tracking system health and automatic adjustments to keep operations running smoothly. The PowerFlex 6000T drives follow speed or torque commands very closely in both open- and closed-loop vector control modes to deliver the precise control required for high performance and large loads. The drives also continuously monitor operations to track the health of electrical components in the drive and motor, and provide real-time diagnostic information to the control system. With this information, users can better predict maintenance requirements well before component failures and take action to prevent unplanned downtime. Additionally, adaptive control features within the PowerFlex 6000T drives help isolate potentially harmful vibration and resonances, and automatically compensate for variances to help keep applications running. — *Rockwell Automation Inc., Milwaukee, Wis.* ■
www.rockwellautomation.com

Gerald Ondrey

Leveraging Time-Series Data to Empower Process Experts

Using new analytics technologies to address process challenges and improve production makes business sense

Chemical manufacturers are continuously challenged to achieve operational excellence. Many factors are involved with reaching this goal. However, one crucial path forward is being able to fully leverage sensor-generated time-series data by being able to analyze it. Companies realize this, but without the proper tooling, they struggle to achieve this objective.

Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com), a global manufacturer and marketer of differentiated and specialty chemicals, was able to overcome this challenge by empowering their process experts with self-service analytics. This tooling enabled them to answer three of the top production questions every organization like theirs is faced with:

- What is happening in the process?
- Has this happened before?
- Why is this happening?

Self-service analytics

With the self-service analytics platform supported by TrendMiner (Houston; www.trendminer.com), Huntsman process engineers and operators are able to search through historical data to look for good and bad production behavior, allowing them to carry out the analytics themselves. They can create "fingerprints" of ideal operating zones, and set monitors against these fingerprints. If a deviation occurs, alerts are sent out via messages, emails or dashboards to notify personnel about the issue, giving them time to take corrective action. A 24-hour engineering support system is therefore set in place, covering times when engineers are not on site (Figure 1). Additionally, self-service analytics can enable process experts to set monitors to predict performance and send out early warnings, and can even be used in conjunction with Lean Six Sigma continuous improvement projects.

Huntsman has also been able to eliminate data silos. Like many manufacturing companies, their operational data was traditionally kept in separate silos, each within its specific teams and process/business applications. With self-service analytics, users can contextualize, centralize, save and share their operational data with all teams. By eliminating these silos, it became possible to move toward combined organizational production overviews for all sites, both locally and globally. With this shared information, they saw global collaboration and team efficiency improve, which resulted in enhanced and more insightful resolution of production problems.

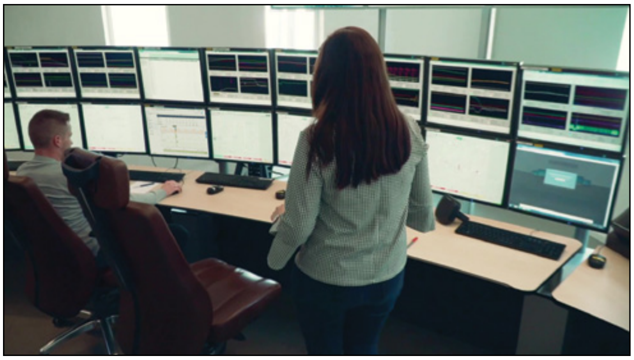


FIGURE 1. Self-service analytics monitoring capabilities provide 24-hour engineering support

Fingerprinting batch processes

Traditionally, Huntsman's teams would check batch profiles using Microsoft Excel — an approach that required a substantial amount of production expertise and time. However, after implementing a self-service analytics platform in 2018, they were able to become much more efficient by creating fingerprints of good operating zones to check batch quality against specifications.

In one of its polyols processes, distinct pressure and temperature profiles are required to consistently produce high-quality material. Huntsman's teams used fingerprints as realtime monitors to continuously check the process for deviations. Process experts were able to quickly identify subtle disturbances that would be difficult to capture in a numerical model. As the monitors gave early warnings for unexpected heat input, there was no need to check afterward if there were any abnormalities, allowing operators to take appropriate action in time (Figure 2). This new approach to batch analysis and monitoring led to a significant reduction in off-specification batches and a significant increase in product quality.

Improving quality assurance

In one of Huntsman's Advanced Materials plants, numerous batches in a wiped-film evaporator exceeded the solvent specification limit, resulting in off-specification products. The process experts also observed a multiyear drift in quality as measured by the quality assurance laboratory. They suspected this problem resulted from a change in testing methods, but this hypothesis and the frequency of off-specification production needed to be investigated.

A six-sigma analysis following the "define, measure, analyze, improve and control" (DMAIC) strategy was performed using the various capabilities of self-service analytics, such as value-based searches, layer comparisons, statistical comparison tables, scatterplots, filtering and the recommendation engine.

The team used scatter plots to easily track batch performances for insight about which batches were

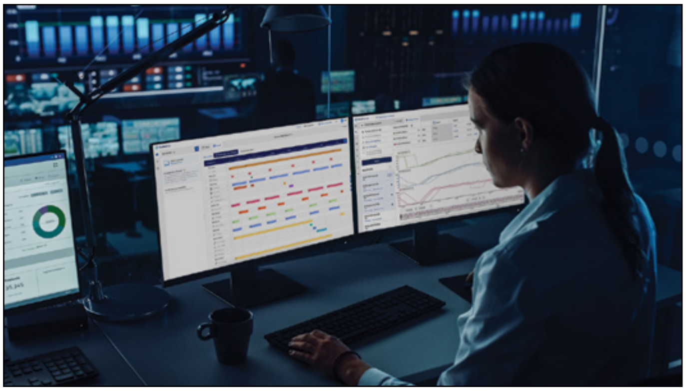


Figure 2. Setting process monitors can give process experts early warnings when batch quality is off-specification

outside of the acceptable operating zone. Multiple differences between the plant's on-specification and off-specification production campaigns were found, which convinced them that long-term changes had been occurring in the process. Further investigation allowed the process experts to rule out the misreading of flowmeters, and they found a non-negligible offset between measured and true pressure.

With self-service analytics, the process experts completed a faster root-cause analysis on a much larger data set. They were also able to identify differences in the subtle pressure readings and thus call for more tests to be conducted. Based on these findings, quality improvements were realized within days after making process changes.

Using new technology like self-service analytics can effectively address process challenges and vastly improve production. Huntsman understands this. Now, its teams of process experts have a continuous, constant view of production, resulting in more profitable and efficient production management in a highly competitive market. ■

Edited by Mary Page Bailey

Authors

Jasper Rutten (Email: jasper_m_rutten@huntsman.com) works at Huntsman Corp. as the manager of the company's Advanced Analytics team, which sets out the global route on digitalization and advanced analytics for upstream methylene diphenyl diisocyanate (MDI) manufacturing facilities. He joined Huntsman in 2000 after graduating as a chemical engineer from Twente University in the Netherlands. His extensive experience in chemical engineering provides a solid basis to lead the global journey of sustainably bringing industry 4.0 into practice.

Edwin van Dijk (Email: edwin.vandijk@softwareag.com) is the vice president of marketing at TrendMiner NV (www.trendminer.com). He has over 20 years of experience in the process and power industries. He spent more than 10 years at Greenock, selling plant design software to owner-operators and contractors, followed by a role as business development manager at BlueCielo ECM Solutions. In his last role as director of global marketing at BlueCielo, he focused on brand recognition, product positioning and go-to-market launch plans. Within TrendMiner, van Dijk is responsible for the global marketing strategy, which includes a focus on educating the market on the benefits of data analytics in the process industry and the opportunities available with TrendMiner's solutions.

New Products

Digitize weighing processes with this balance and software

The combination of XPR series balances and LabX Software (photo) enables users to digitalize laboratory weighing processes and ensure accurate results, full traceability and data integrity. LabX Balance software integrates fully with laboratory-information systems, such as chromatography software, and enables a seamless flow of data throughout the entire analysis workflow. LabX sends weighing results directly to where the weight values are required for subsequent analyses and ensures traceability back to the starting point. Now available in Version 12, LabX software guides users through SOP workflows on all connected XPR Balances, including the new XPR automatic balance, to ensure every operator follows the same procedures. — *Mettler-Toledo GmbH, Greifensee, Switzerland*
www.mt.com

A new rupture disc is ASME BPE compliant

The new IntegrX-HPX rupture disc (photo) addresses the need to improve process performance, reliability and safety within the biopharmaceutical industry. The IntegrX-HPX combines the unrivaled performance of the company's HPX with ASME BPE (bioprocessing equipment) compliant crevice-free design, removing the need for integral seals. Manufactured and tested to optimize service life and performance, the IntegrX-HPX is a semi-circular, scored, reverse-acting rupture disc is suited for cyclic process conditions from full vacuum to 95% of the stamped rating. With the disc built into a cartridge, the robust welded design of the IntegrX-HPX mitigates the impact of downstream piping loads on the disc burst pressure and overall performance. — *Continental Disc Corp., Liberty, Mo.*
www.contdisc.com

Bringing artificial intelligence to asset-performance management

The launch of Ability Genix Asset Performance Management (APM) Suite (photo) brings next-generation artificial-intelligence (AI)-based predictive maintenance, asset reliability and integrity insights to the chemical process and utilities industries. Genix APM is an enterprise-grade application to monitor assets, prescribe maintenance actions, improve equipment utilization and support lifecycle analysis and capital planning. By assessing the remaining useful life of industrial assets, Genix APM generates a plan for preventive maintenance, which can extend equipment uptime by as much as 50% and increase asset life by up to 40%, says the company. The Genix APM Suite makes it easy to add condition monitoring to existing operational technology (OT) landscapes, enables prioritization of maintenance activities based on AI-informed predictions and provides a comprehensive overview of asset performance. — *ABB Ltd., Zurich, Switzerland*
www.abb.com

Raising the bar for heat pumps up to 95°C

The RedGenium heat pump, combined with the new Grasso V XHP reciprocating compressor (photo), enables the provision of temperatures of 95°C with high efficiency. In addition to the temperature advantage, the largest V XHP compressor also offers almost double the capacity compared to previous models. The new system is well-suited for many processes with high heat-load requirements. Electrically driven heat pumps can replace conventional fossil-fuel-based heating systems. They use either available process waste heat or other heat sources from the environment and transfer the heat to a high temperature level. — *GEA Group AG, Düsseldorf, Germany*
www.gea.com

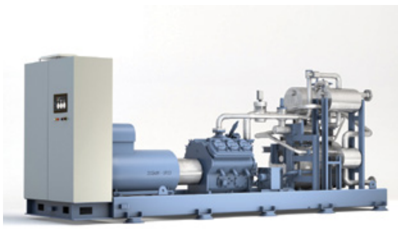
Web-based platform streamlines molecule discovery chemistry

Last month, this company released Torx Test and Torx Analyze (photo) to complete the Torx platform — a single web-based solution that enables drug discovery teams to work together, share knowledge, manage resources and track progress throughout the design-make-test-analyze (DMTA) workflow. Torx Test connects chemists and assay scientists to enable seamless scheduling, management and results delivery for biological, physico-

Mettler-Toldeo

Continental Disc

ABB



GEA Group

Torx Software

chemical and other assays. It removes the administrative burden from the testing process by providing a platform to submit requests upon compound registration, as well as followup requests from Torx Make and monitor progress in realtime. Torx Analyze combines 2D and 3D analysis of molecule data loaded from corporate databases with the extensive information sharing and molecule design capabilities of Torx Design. — *Torx Software Ltd., Cambridge, U.K.*
www.torx-software.com

New touchscreen coulometer for gas-stream analysis


UIC

The CM5016 C/S coulometer (photo) provides highly accurate, absolute determination of carbon or sulfur content in any gas stream containing CO_2, SO_2 or H_2S. The coulometer is used as the detector with a sample-acidification front-end unit, detecting carbon or sulfur (or both) in the range of 0.01µg to 100 mg. The CM5016 coulometer is equipped with a new 12-in. touchscreen display assembly for enhanced user interface. — *UIC, Inc., Joilet, Ill.*
www.uicinc.com

Manage the automation lifecycle of water and wastewater units

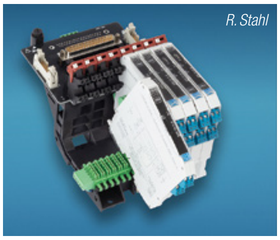
The newest release of the EcoStruxture Automation Expert system, Version 21.2 (photo), provides complete lifecycle management, seamless integration of IT/OT services and improved system diagnostics for automation systems in water and wastewater treatment plants. EcoStruxure Automation Expert allows for automation software to be separated from the hardware, providing more versatility for enterprises to break their dependency on proprietary hardware suppliers. EcoStruxure Automation Expert aims to provide a single platform that evolves with time for water and wastewater subsegments, including: treatment infrastructures (including desalination plants and industrial wastewater), network infrastructures and other water resources, such as irrigation systems. EcoStruxure Automation Expert offers seamless connection to many engineering software platforms, so new designs or changes can be validated virtually. — *Schneider Electric USA, Andover, Mass.*
www.se.com/us


Schneider Electric USA

Fast, safe integration of Ex i isolators

The pac-Carrier 9295 (photo, p. 23) is a new, space-saving integration solution for this company's 12-mm ISpac Ex i isolators. This significantly simplifies the installation and wiring of isolators to input/output (I/O) cards in automation systems from all manufacturers. Prefabricated connecting cables reduce the risk of wiring errors. Further-

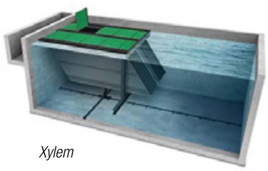
more, the installation time is reduced by up to 40% thanks to the isolators' tool-free mounting, says the company. This integration solution is particularly suited for projects involving a high number of channels. The new pac-Carriers are available in 8- and 16-slot versions, thereby enabling up to 32 signals to be connected. The variant with eight slots is only 110 mm wide. An additional HART multiplexer coupling only requires 36 mm of extra space. ISpac devices and the pac-Carriers are approved for use in Zone 2 decentralized installations. The pac-Carrier can also be used for functional safety applications up to safety integrity level (SIL 3). — *R. Stahl AG, Waldenburg, Germany*



www.r-stahl.com

New clarifier has a large settling area within a small footprint

The Leopold Texler lamella clarifier (photo) for water treatment uses a series of inclined lamellas designed to fit into rectangular clarification basins, providing a large settling area within a small footprint. With its efficient removal of solids, the clarifier attains very low turbidity levels and improves the filterability of water. The lamella sheets are installed at a 55-deg angle, increasing the treatment capacity by up to 100% compared to conventional sedimentation systems, says the manufacturer. Solids settle without blocking the pathway of the water. The unique trough covers have an integrated weir design to ensure even flow distribution throughout the length of the clarifier. Texler's lamellas are made from a hydrophobic geotextile high-density polyethylene (HDPE) that has water-repellent and flexible properties to prevent sludge accumulation on the lamella sheets, reducing the need for regular cleaning. — *Xylem Inc., Rye Brook, N.Y.*



www.xylem.com

Enhance EHS compliance and education with this new learning system

This company launched a new learning management system (LMS) with expanded capabilities for increased flexibility, functionality and scalability. The new LMS will also integrate the SAP Litmos tool as part of its offering. With an easy-to-navigate user interface, and simplified administration and content management, the new LMS offers a wealth of learning content related to environmental, health and safety (EHS) compliance. The new system also includes robust and flexible reporting, as well as social learning and gamification features with badging and leaderboards. — *DuPont Sustainable Solutions (DSS), Wilmington, Del.*

www.dsslearning.com ■

Mary Page Bailey and Gerald Ondrey

Facts At Your Fingertips

Cake Filtration Basics

Department Editor: Scott Jenkins

Filtration is arguably the most common unit operation in the chemical process industries (CPI). Filtration processes can be divided into three broad categories: cake filtration, where the incoming slurry contains enough solid material to form a cake on the filter medium; clarifying filtration, which involves feeds with solids levels that are too low to form a cake and where the solids become embedded in the filtration medium; and crossflow filtration, where the feed flows parallel to the filtration surface, rather than the conventional perpendicular flow. This one-page reference summarizes the basic operation and mechanism for cake filtration processes.

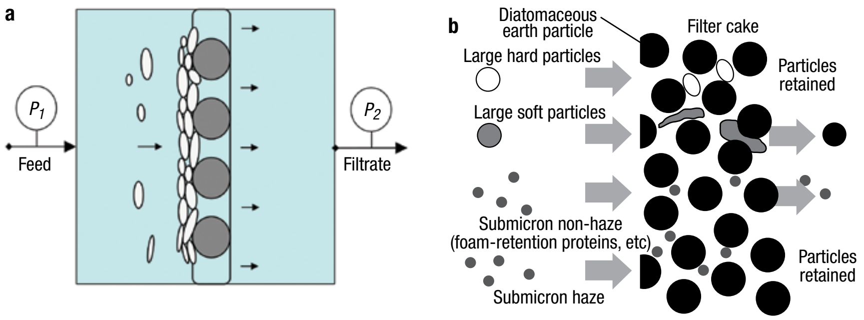


FIGURE 1. In cake filtration (a), the separation takes place on a buildup of particles (cake) on the filter medium. In some cases (b), more than simple size exclusion may be involved

Cake formation

In cake filtration, feed is introduced upstream of the filter, and a layer of solids is deposited onto the surface of the filter medium. Some of the particles in this layer of material bridge the gaps between the fibers of the filter medium, a process known as bridging. Subsequently, new particles are deposited onto this existing layer, forming a second layer of solids. The concept is depicted in Figure 1a, where the dark circles represent the solid portion (for example, fibers) of the filtration medium, and the gaps between the circles denote the flow path for filtrate. The process continues, with new solids forming additional layers adjacent to solids already deposited, and in this manner, a cake forms. Rather than the actual medium, the cake itself acts as the filtration medium, determining the quality and flowrate of the filtrate. The role of the actual medium is only to support the cake.

Cake filtration is suitable only for feeds containing enough solids to form a cake — at least 1 vol.%. Higher levels of feed solids lead to better results, including improved bridging and more porous cakes.

Media types

There are a variety of media available, including paper, textiles, polymers, and even wire screens. Among the materials used are polyolefins, nylon, polyester, acrylics and fluorocarbons. Both woven and nonwoven media are employed, over a wide range of porosity. When selecting a medium, consider mechanical strength, chemical compatibility with the process material, temperature tolerance, ease of cleaning and porosity. If the medium is too coarse, solids may become lodged in the openings, leading to blinding. In other cases, solids may not be retained and bridging may not occur. Conversely, a medium that is too tight will impose an unnecessary restriction to liquid flow, leading to reduced productivity.

Filtering soft solids

Solids that are soft, slimy or gelatinous tend to pack tightly, forming cakes of low permeability. This problem can be alleviated by the addition of a small amount of filter aid to the feed slurry. Filter aids are inert, highly porous materials that act to separate blinding solids, leading to a more open cake and in turn a higher filtration rate. Filter aid added directly to the slurry is known as body feed. Alternatively, prior to introducing the feed slurry, a layer of filter aid can be deposited onto the filtration medium to form what is known as a precoat.

Filter aid

Several types of filter aid are available. Most common is diatomite (diatomaceous earth), the skeletal remains of single-cell algae, composed primarily of silica. Diatomite offers the highest clarity of all types of filter aid. Another option is perlite, which is milled volcanic glass composed mainly of potassium aluminum silicate. Because perlite is not as tortuous as diatomite, the high clarity levels achievable with the latter are not possible. Nevertheless, perlite may be more cost effective than diatomite for separation of coarse particles. This is because the density of perlite is lower, so that less material is needed to form a precoat of a given thickness. Other types of filter aid include expanded cellulose.

Cake filtration mechanism

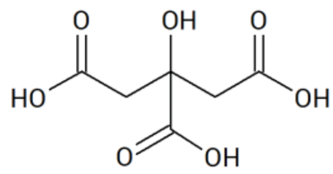
A filter precoated with diatomaceous earth (DE) is represented in Figure 1b. This diagram shows how filtration by simple size exclusion may be an oversimplification. At the top of the figure, rigid particles larger than the openings in the DE precoat are retained, while smaller ones pass through, consistent with expectations. However, the compressible nature of the large, soft particles shown in Figure 1b allows them to squeeze through, even though the particles are smaller than the openings.

The sub-micron, non-haze particles shown in the figure also are not retained, but this is expected because these particles are smaller than the pores in the cake. On the other hand, the sub-micron haze particles seen at the bottom of the diagram are retained even though they are larger than the openings. This is attributable to some mechanism other than physical exclusion, perhaps electrostatic or hydrophobic interaction. ■

***Editor's note**: This column is an excerpt of the following article: Gabelman, A., An Overview of Filtration, *Chem. Eng.*, November 2015, pp. 50–58.*

Production of Citric Acid

By Intratec Solutions



Citric Acid

FIGURE 1. Citric acid is used in a variety of applications, including for taste in foods and beverages

Citric acid is a naturally occurring tricarboxylic acid commonly found in plants and animals (Figure 1). In its pure form, it is a colorless compound readily soluble in water. Citric acid is mainly used to add taste to food and soft drinks, and as acidulant for dietary supplements and pharmaceuticals. It is also used as the following: an anticoagulant; mineral flotation agent; industrial cleaning/electroplating/anodizing reagent; animal food additive (digestion aid); and water treatment agent. Citric acid can be used in the manufacture of other products, including: dibasic ammonium citrate; ammonium ferric citrate; calcium citrate; citrazinic acid; citrated fatty acid glycerides; lithium citrate; potassium citrate; sodium citrate; tri-*n*-butyl citrate; and triethyl citrate

Citric acid can be obtained from natural sources (for example, lemons, limes and oranges) and can be synthetically produced either via chemical reaction or microbial fermentation. Large-volume industrial production of citric acid, however, is based almost exclusively on microbial fermentation of a carbohydrate substrate, in which a strain of *Aspergillus niger* is employed to convert sugar to citric acid. Raw materials commonly used are molasses, sugar (raw beet, refined beet), cane sugars, syrups (prepared from wheat, corn, potato or other starch).

Production process

Citric acid production from corn starch comprises three major sections: (1) corn starch saccharification; (2) fermentation; and (3) products treatment (Figure 2).

Corn starch saccharification. Corn is fed to hammer mills to be crushed into a coarse grind meal containing all kernel components. This meal is routed to a liquefaction vessel, along with hot process condensate and alpha-amylase enzymes. The corn starch is enzymatically hydrolyzed, producing maltose and higher oligomers. The slurry from this step is sent to a saccharification tank, where it is mixed with gluco-amylase enzymes, which cleave the maltose and higher oligomers into glucose.

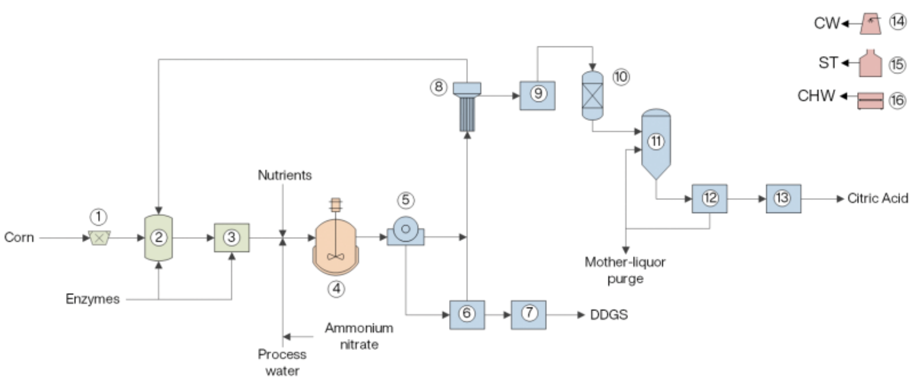
Fermentation. Glucose is mixed with process water, nutrients and ammonium nitrate, and fed to the fermenters. Fermentation is performed in fed-batch mode and under aerobic process conditions in agitated, jacketed fermentors. After glucose exhaustion, the batch phase is finished, and the fed-batch phase is started. During the fed-batch phase, glucose and nutrients are continuously supplied.

Products treatment. After the fermentation step, the fermentation broth is sent to a rotary vacuum filter, separating non-fermented biomass (which is sent to a wash step) from a liquid stream containing citric acid that is routed to the evaporation stage. The biomass is centrifuged and washed for citric acid recovery, which is sent to evaporation, while the biomass cake is dried in a rotary dryer, generating dried distiller's grains with solubles (DDGS) byproduct. In the evaporation step, the broth is concentrated, and then sent to chromatographic separation equipment to remove biomass residues, while the vapor is condensed and recycled to the liquefaction area. The citric acid solution is then fed to ion-exchange column for separation of magnesium and potassium ions, and to a crystallizer, forming citric acid crystals, which are routed to a vacuum filter to be separated from the mother liquor. Most of this liquor is returned to crystallization upstream, but a fraction of it is purged to avoid impurities build-up. The solid citric acid cake is directed to a rotary dryer to remove residual water, then sent to blending silos and packaging, from which bulk and bagged citric acid are obtained, respectively.

Product grades

The uses and applications of citric acid vary according to the product grade. The main forms of citric acid are: U.S. Pharmacopeia (USP) grade; reagent grade; and monohydrate grade. This organic acid may be produced in crystalline form, anhydrous, with several granulations; or in solutions with different concentrations (for example, 50% w/w), with grades varying in appearance, purity and color. ■

Editor's note: The content for this column is developed by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are based on publicly available and non-confidential information. The content represents the opinions of Intratec only.



1. Grinding mills
2. Liquefaction
3. Saccharification
4. Fermentors
5. Biomass separator
6. Biomass washing
7. Biomass drying
8. Evaporator
9. Chromatographic separation
10. Ion exchangers
11. Crystallizer
12. Vacuum filter
13. Citric acid dryer
14. Cooling tower
15. Boiler
16. Chiller

CW Cooling water
ST Steam
CHW Chilled water

FIGURE 2. The diagram shows a process for making citric acid by fermenting corn sugars

Unlocking Hydraulic Limits in a Revamp

Follow the practical tips discussed here to accelerate hydraulic revamp projects and increase the success rate

Nattapong Pongboot
Global R&D

IN BRIEF

REAL-LIFE DILEMMAS

THEORY VERSUS REALITY

TEST-RUN BEST PRACTICES

EXECUTION PLAN

EXAMPLE 1: HYDROCRACKER FEED PREHEATER

EXAMPLE 2: INCREASED WASH WATER FLOW

EXAMPLE 3: INCREASED DIESEL PRODUCTION

EXAMPLE 4: IMPROVED DIESEL RECOVERY

ADDITIONAL TIPS

Conducting a thorough hydraulic check is a crucial part of a successful plant revamp. Depending on the remaining margin of the hydraulic system, a certain degree of modifications may be required to accommodate a new unit throughput or configurations.

Conventional hydraulic calculations can be time-consuming, involving engineering documents, possibly with expensive hydraulic calculation software. This article provides helpful tips to significantly reduce the person-hours required for hydraulic review. Also, unorthodox, yet practical, methods for equipment sizing will be demonstrated as fast-track solutions to unlock hydraulic constraints at a chemical process industries (CPI) facility. These tips and methods come out of the author's experience as a plant operator and designer, and are illustrated with several real-world examples.

Real-life dilemmas

As a former petroleum-refinery process engineer, the author had opportunities to work with multiple reputed design companies on different revamp projects. Surprisingly often, these companies applied hydraulic design criteria intended for new units to revamp projects without a thorough understanding of why these criteria were there in the first place. As shown in Table 1, many of these criteria, such as pressure drop per 100 m, are primarily based on economics (capital expenditures versus operating expenses) and only intended to provide an economical solution to new unit designs. This approach does not apply in the case of revamp projects, where a design engineer should seek to exploit every bit of design margin to avoid costly equipment modifications. It must be noted that piping changes are generally expensive and undesirable in most revamp projects.

I would like to stress that conflicting with these hydraulic design guidelines does not mean your existing equipment cannot be used in revamp scenarios unless they are integrity or reliability criteria (for example, erosion limit). More importantly, the economic justification is different here, as the investment in the existing equipment has already been made. Utilizing existing hardware is always a better choice from a financial and practical perspective, thus requiring a careful hydraulic assessment.

Another essential concept that was often missing is practicality. Many engineers from these design firms solely relied on theoretical hydraulic calculations and ignored the real-world data, such as pressure survey data. While the author always offered test-run data (or the opportunity to do test run), many failed to use them properly. To make matters worse, some of these engineers confidently said that there was no such need for plant data, as they thought they could figure out everything based on their computer software. The author has experienced multiple disastrous revamp projects that failed to meet the revamp objectives just because

FIGURE 1. The photo on the left shows the inner pipe wall of a severely fouled fuel oil line. The photo on the right shows a tube bundle heavily fouled by asphalt and coke. Both examples are nonidealities illustrating why ideal hydraulic models deviate from reality

TABLE 1. EXAMPLES OF LINE DESIGN CRITERIA TYPICALLY USED BY ENGINEERING COMPANIES

		Recommended high limits	
Item	Detail	ΔP/100 m, bar/100 m	Velocity, m/s
1	Pump suction lines (bubble point fluid)	0.11	1.8
2	Pump discharge lines (carbon steel)	0.91	6.1*
3	Amine piping (stainless steel)	0.34	3*
4	Reboiler inlet line	0.07	1.5

*Integrity criteria
Many of these values are based on economic criteria, while some are intended to ensure piping integrity

the designer did not incorporate actual plant data and equipment performances during the design phase.

Moreover, people tend to overly focus on rotating equipment. Throughout my experience with revamps, the suggestion has been made by former colleagues that solving hydraulic issues could be accomplished by replacing pumps and compressors. This notion is not always the case, and could lead to a costly solution, like replacing a large compressor. Ask yourself if you would still replace a pump or compressor if you found that the inlet block valve was accidentally closed. More often than people think, pump and compressor issues do not result from the equipment itself.

These situations might sound unreal to some readers, but they are based on true stories. Some people do not view through a different lens when dealing with revamps, regardless of how experienced they are.

Theory versus reality

Theoretical hydraulic calculations are undoubtedly good estimations, but it is important to remember that engineering assumptions or even hydraulic models themselves (such as Darcy-Weisbach or Hazen-Williams models) may not perfectly represent the real world. For example, the hydraulic design assumptions listed in Table 2 might be reasonable for a new design. However, it does not mean that the hydraulic model developed using the same assumptions will reflect exactly what happens in the existing hydraulic system.

This difference between theory and reality is the primary reason why a design margin is always applied when designing a new piece of equipment or device. The margin accounts for any non-idealities and provides additional operational flexibility. Almost all process piping, pumps and compressors are designed based on rated flowrates — typically 110–120% of normal. Therefore, 10–20% spare capacity may be available for the revamp operation.

Some examples of non-idealities in hydraulic systems include fouling, corrosion, erosion and so on. A piping system or asset might be fouled (or corroded), thus affecting both actual pipe roughness and flow area to a certain degree (Figure 1).

More interestingly, some revamp projects are effectively a remedy for a previous grassroots design that failed, so repeating the same mistakes by only relying on theories

NOMENCLATURE

ΔP/100 m	Pressure drop per 100 meters
D	Nominal pipe diameter
NPSHa	Available net positive suction head
C_v	Flow coefficient
$\%Travel$	Valve travel
Q_{revamp}	Actual volumetric flow rate for the revamp case
S.G.	Specific gravity at the corresponding operating temperature
$\%Travel_{base}$	Valve travel for the base case
$C_{v,base}$	Flow coefficient for the base case
ΔP_{base}	Pressure drop across the control valve for the base case
ΔP_{revamp}	Pressure drop across the control valve for the revamp case
$\Delta P_{new\ equipment}$	Pressure drop across the new equipment
$C_{v,revamp}$	Flow coefficient for the revamp case
$\%Travel_{revamp}$	Valve travel for the revamp case
Q_{total}	Total actual volumetric flowrate across the main control and bypass valve
Q_{main}	Actual volumetric flow rate across the main control valve
Q_{bypass}	Actual volumetric flow rate across the bypass valve
$C_{v,total}$	Total flow coefficient across the main control and bypass valve
$C_{v,main}$	Flow coefficient for the main control valve
$C_{v,bypass}$	Flow coefficient for the bypass valve
ΔP_{total}	Total pressure drop across the main control and bypass valve
ΔP_{main}	Pressure drop across the main control valve
ΔP_{bypass}	Pressure drop across the bypass valve
$C_{v,total,revamp}$	Total flow coefficient for the revamp case
ΔH_{base}	Pump's head for the base case
ΔH_{margin}	Design margin for the pump's head
ΔH_{revamp}	Pump's head for the revamp case
$\Delta H_{polytropic}$	Compressor's polytropic head
$\Delta H_{polytropic,base}$	Compressor's polytropic head for the base case
$\Delta H_{polytropic,revamp}$	Compressor's polytropic head for the revamp case
Q_{inlet}	Actual inlet volumetric flowrate
$Q_{inlet,base}$	Actual inlet volumetric flowrate for the base case
$Q_{inlet,revamp}$	Actual inlet volumetric flow rate for the revamp case

does not make sense. This situation further emphasizes the need to augment theoretical calculations with real-world data when one handles a revamp work.

Test-run best practices

One of the objectives of a unit test run is to determine the actual performance capabilities and constraints of

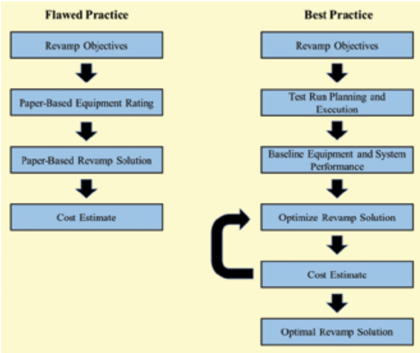


FIGURE 2. To improve success and minimize capital cost, the author recommends the workflow illustrated on the right and avoiding that on the left

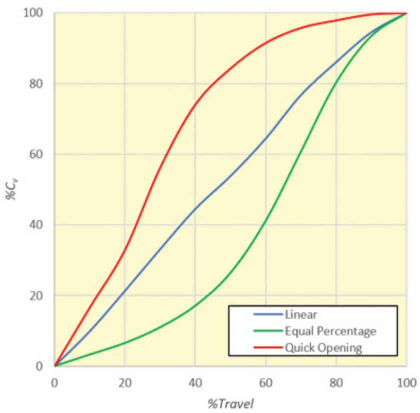


FIGURE 3. The relationship between C_V and valve travel remains virtually the same for any hydraulic system, so it indicates hydraulic availability

an existing system. Process calculations and solution findings based only on theoretical equipment performance may be misleading. A test run is a perfect opportunity to unveil all underlying design margins, which might not be explicitly shown in the equipment datasheet.

A good example is a typical pump-sizing workflow. Several parties, including the licensor, the EPC (engineering, procurement and construction) contractor and pump manufacturer, often add design factors (usually arbitrary and based on institutional knowledge) to each design stage

When assuming a typical design margin of 10%, the compounded design margin that results from each party's addition could be as large as 33% (1.10 to the power of 3) by the time the pump is at the installation site. It is not uncommon to see a pumping system with a highly throttled flow control valve. In some cases, one might need to replace or trim the impeller to improve pumping operation and save energy.

TABLE 2. EXAMPLES OF EQUIVALENT LENGTHS FOR PIPING COMPONENTS

Piping component	Detail	Equivalent length
Gate valve	Full bore	8–13 *D*
Check valve	Swing type	92–135 *D*
Butterfly valve	8 in. and larger	20–40 *D*
Elbow	90 deg, $R = 1.5$ *D*	13–20 *D*
Tee	Flow-through branch	60–72 *D*

These numbers vary by organization and are primarily intended for the design mode

Moreover, it is also highly beneficial to use the test run data to establish a base case for your revamp and improve the calculation accuracy.

Ignoring the actual equipment and system performances can lead to a situation in which the maximum capacity of the existing equipment is substantially underrated or overrated. Test-run data and observations should be reviewed and discussed with the concerned parties to avoid recommending a change that conflicts with the operational data. For example, the control valve was too small considering the past operational data, but it is not replaced during the revamp execution. In the worst-case scenario, the revamp could fail, as the designer may not address the real issues.

Test runs should be conducted comprehensively at high unit throughputs to ensure that the pressure drop between the measurement locations is more significant than the error of the pressure instruments. As a best practice, preliminarily check your remaining margins before the actual test run. Simulating expected process conditions as a test-run guideline would be helpful.

There is no harm in exceeding the design unit capacity. The real constraints are those observed in the field, such as valve travel or motor load, rather than design values on paper. As mentioned earlier, we are trying to utilize all hidden margins and define a new baseline here. If your existing hardware limits the maximum throughput, some actions can be taken during the test run, for example, opening a bypass valve or starting a spare pump. Altering process conditions, such as raising the pressure or level of the suction vessel to increase pump discharge pressure and available net positive suction head (NPSHa), would also help. The author recommends incorporating past equipment inspection and reliability records into the analysis.

This new performance baseline can be developed by measuring flows, temperatures and pressures with well-calibrated instrumentation and analyzing the process streams. Field measurements and checks are highly recommended when deemed applicable, such as a single-gage pressure survey.

In addition to the aforementioned standard process variables, other test-run observations should also be documented, such as: control-valve travel and response; motor load/speed or turbine load/speed; signs of cavitation at pumps and control valves; vibration and noises; and others.

Before using test-run data further, always verify, correct and reconcile it to improve data quality.

Execution plan

As mentioned previously, relying on theoretical calculations can lead to a costly revamp or even a total failure.

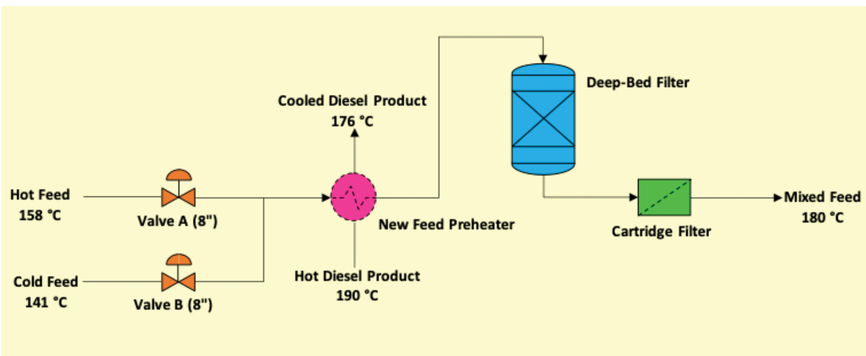


FIGURE 4. The diagram represents the hydrocracker feed system discussed in Example 1 with its new feed preheater

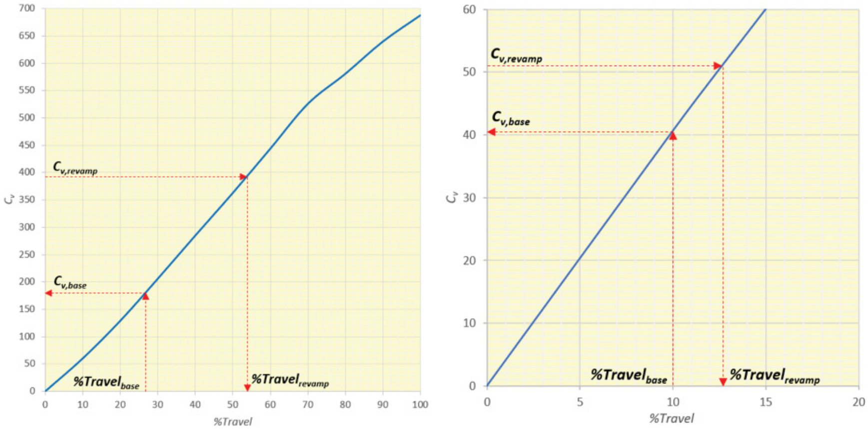


FIGURE 5. The graphs show determinations of $C_{v,base}$ and *%Travel$_{revamp}$* in Example 1. On the left is Valve A (linear – full-scale), and on the right is Valve B (equal percentage – magnified)

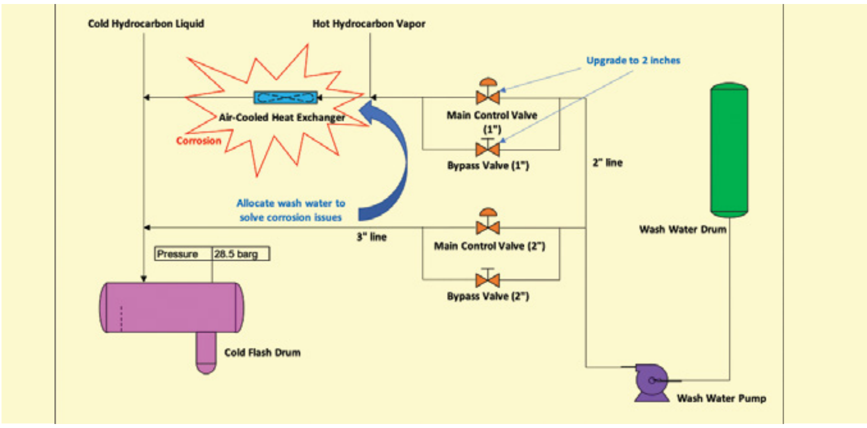


FIGURE 6. The diagram illustrates a wash-water injection system of a single-stage hydrocracker, as discussed in Example 2

The author recommends following the best practices illustrated in Figure 2 rather than using 100% paper-based calculations, which is generally a flawed practice.

In general, the revamp solution of hydraulic debottlenecking projects can be developed using the following approaches:

Smart use of equipment's characteristics. The characteristics of the equipment or device are usually well-defined, if not subjected to severe fouling or damage, and are practically independent of the hydraulic system (such as the valve characteristic curves in Figure 3). In conjunction with good baseline data, these characteristics are more than adequate to check the hydraulic adequacy of the existing system or even design a new control valve or pump. This technique usually employs the simplest mathematical equations (flow coefficient (C_v) equation), and small amounts of process data, thus requiring minimal effort. The author recommends first trying this simple yet effective technique before setting up the full-hydraulic model.

Using the fully-calibrated hydraulic model. As an initial step, a design engineer must select a proper hydraulic model. For example, the Hazen-Williams equation is usually sufficiently good to handle a water distribution system with a relatively smooth pipe surface. However, this equation is not valid for other fluids, therefore requiring the Darcy-Weisbach equation.

Whenever this approach is inevitable, a designer should systematically calibrate the hydraulic model. Typically, the modeler has to adjust multiple tuning parameters to match the actual data. These parameters include the following:

• Pipe roughness: The values from design guidelines rarely match reality due to fouling and corrosion. This parameter is particularly crucial for cast iron or aging piping systems
• Effective pipe diameter: If the hydraulic system is subject to fouling, the modeler can also adjust the effective pipe diameter
• Resistance coefficients and equivalent lengths for piping components: Different design guidelines suggest different values (as highlighted in Table 2). Which one are you going to trust? There is no harm in tuning these parameters

As a minimum requirement, the calibrated hydraulic model should be able to fit two sets of data. If it fails to do so, it usually means the tuning parameters are inappropriate, therefore requiring recalibration. Note that a model calibration does not have to be perfect, but should be at least good enough for decision-making.

Example cases

To better understand how both approaches work, the following real-world examples are discussed here.

1. Hydrocracker feed preheater. In this example, a new feed preheater was to be designed and installed during the refinery turnaround to reduce the energy consumption of a hydrocracker unit. As illustrated in Figure 4, a mix of two liquid feed streams will be heated up by a hot diesel product from a diesel hydrotreater. Subsequently, this mixed-liquid feed stream must go through two stages of filtration to remove solid particulate matter, which can plug the front beds of the hydrocracking reactor.

This new feed preheater must fit into the existing system without causing flow-control issues. As a general guideline, Valve A and Valve B in Figure 4 should have *%Travel* less than 80, a typical maximum *%Travel* for reasonable flow control.

In this case, the refinery conducted a test run at desired revamp flowrates (Q_{revamp}) and with the filter's maximum allowable pressure

TABLE 3. TEST-RUN DATA FOR A NEW PREHEATER DESIGN

Stream	Q_{revamp}, m^3/hour	%Travel$_{base}$	Temperature, °C	S.G.
Hot feed	237.4	26.4	158	0.818
Cold feed	78.2	10.0	141	0.820

FIGURE 7. The location of the injection point discussed in Example 2 (highlighted by the red circle) challenges modification

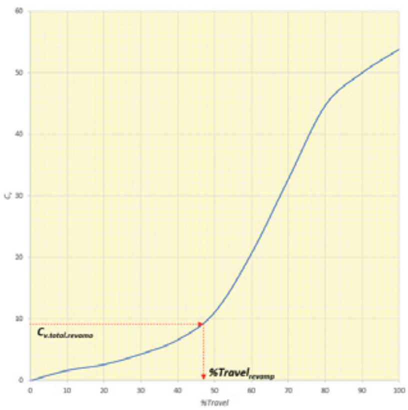


FIGURE 8. The graph shows the determinations of $\%Travel_{revamp}$ for a full-bore 2-in. control valve, as discussed in Example 2

drops as the worst-case scenario (see Table 3). Note that Q_{revamp} for each stream is based on the specific gravity at the corresponding operating temperature.

Instead of performing a detailed calculation, the characteristics of control valves can alternatively be utilized to save substantial effort required for the hydraulic review, as described in the following steps:

1. First, determine the baseline flow coefficient ($C_{v,base}$) from the baseline valve travel ($\%Travel_{base}$) as graphically illustrated in Figure 5. Typically, these C_v data can be obtained from vendor's literature, (for example, Fisher's Catalog 12).

2. The next step in the streamlined calculations is to find a baseline pressure drop (ΔP_{base}) using Equation 1.

$$\Delta P_{base} = (Q_{revamp}^2 S.G.) / (C_{v,base})^2 \quad \textbf{(1)}$$

3. After determining ΔP_{base} from Step 2, calculate a revamp pressure drop (ΔP_{revamp}) from Equation 2 based on a pressure drop of the new heat exchanger and associated piping ($\Delta P_{new\ equipment}$).

$$\Delta P_{revamp} = \Delta P_{base} - \Delta P_{new\ equipment} \quad \textbf{(2)}$$

4. Back-calculate a revamp flow coefficient ($C_{v,revamp}$) from Equation 3 based on ΔP_{revamp}

$$C_{v,revamp} = Q_{revamp} \times \sqrt{(S.G. / \Delta P_{revamp})} \quad \textbf{(3)}$$

5. Lastly, back-estimate the revamp valve travel ($\%Travel_{revamp}$), as demonstrated in Figure 5

Assuming a typical $\Delta P_{new\ equipment}$ of 1.5 bar, the calculation (estimation) results of the above steps can be summarized as per Table 4.

From Table 4, the existing system has adequate hydraulic availability to accommodate the new feed preheater with $\%Travel_{revamp}$ less than 80 for both Valves A and B.

Besides this case study, one can also apply this technique to similar revamps, such as adding a new adsorber/filter into the existing system.

2. Increased wash-water flow. An air-cooled heat exchanger of a single-stage hydrocracker unit suffers from ammonium salt corrosion. From a separate study, it was determined that the wash-water flowrate should be increased from 150 to 200 m^3/d to correct corrosion problems by allocating wash water from another parallel injection point, as illustrated in Figure 6. As a precaution, the wash-water flowrate must be below 215 m^3/d to prevent excessive erosion. For this injection point, the operating pressure is relatively constant at 28.5 barg.

The whole piping system is made of a sour-service steel grade (which is expensive and requires a long lead time) and located on a high platform (Figure 7), making piping replacement unattractive.

The control and bypass valve are 1 in. (½-in. trim), with the line size of 2 in. for the concerned piping section. These facts suggest that one can still upgrade the control valve to accommodate more wash-water flow. It is not uncommon to see a piping system with a smaller control valve (and even smaller trim size).

Where applicable, the author recommends using the mathematical relationship proved below along with the test-run data to size the new control valve. As previously mentioned, one can always consider opening a bypass valve to overcome hydraulic limitations during the test run.

In principle, the total flow to the injection point (Q_{total}) is a sum of the flow across the main control valve (Q_{main}) and the bypass valve (Q_{bypass}) as per Equation 4.

$$Q_{total} = Q_{main} + Q_{bypass} \quad \textbf{(4)}$$

By employing a liquid-phase flow coefficient equation, one can rewrite Equation (4) as:

$$C_{v,total} \sqrt{(\Delta P_{total}/S.G.)} = C_{v,main} \sqrt{(\Delta P_{main}/S.G.)} + C_{v,bypass} \sqrt{(\Delta P_{bypass}/S.G.)} \quad \textbf{(5)}$$

In reality, all pressure-drop terms (ΔP_{main}, ΔP_{bypass}, and ΔP_{total}) are practically identical. As demon-

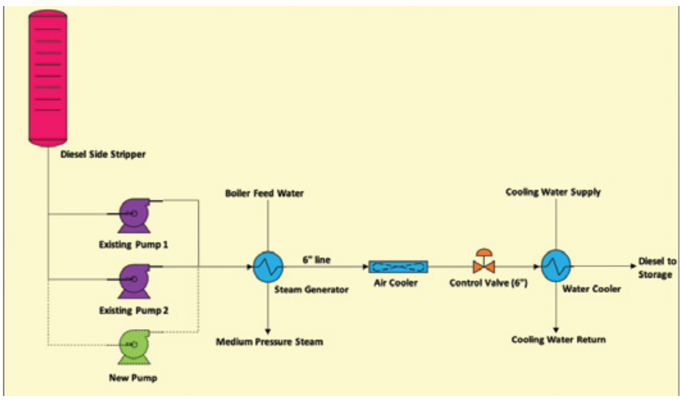


FIGURE 9. The diagram shows the scheme discussed in Example 3 of the existing diesel rundown system, with the third pump highlighted in green

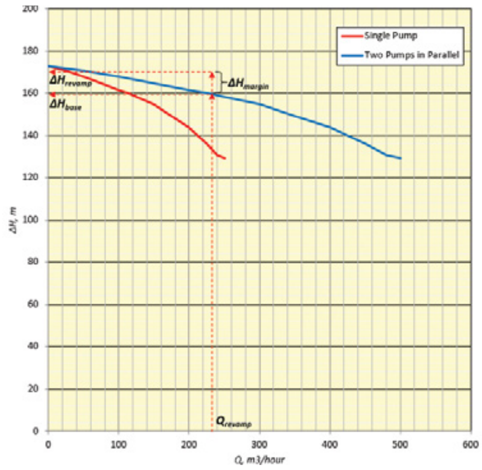


FIGURE 10. The graph shows the ΔH_{base} and ΔH_{revamp} estimate, as discussed in Example 3. A composite pump curve (blue) represents parallel operation

TABLE 4. CALCULATION/ESTIMATION RESULTS FOR STEPS 1 TO 5

STEP	1	2	3	4	5
Component	$C_{v,base}$	ΔP_{base}	ΔP_{revamp}	$C_{v,revamp}$	$\%Travel_{revamp}$
Valve A	180.0	1.90 bar	0.40 bar	391.8	54.0
Valve B	40.6	4.06 bar	2.56 bar	51.1	12.6

strated in the previous example, the designer can apply the same method to determine the flow coefficient for the main control valve ($C_{v,main}$) and bypass valve ($C_{v,bypass}$). Accordingly, one can estimate the total flow coefficient for each scenario ($C_{v,total}$) from Equation (6).

$$C_{v,total} = C_{v,main} + C_{v,bypass} \quad (6)$$

Besides liquid-phase applications, Equation 6 also applies to other applications, such as gas phase or steam. During the test run, the bypass valve was opened to explore the maximum wash-water rate at this injection point. Table 5 summarizes the test-run data and calculation results.

Although opening a bypass valve can achieve the revamp flowrate, it can also lead to undesired situations, including vessel overflow. As such, a design engineer has no choice but to upgrade the existing 1-in. control valve. In this case, a full-bore 2-in. valve could be a good fit. From Table 5, the total flow coefficient of the revamp case ($C_{v,total,revamp}$) is 9.14. Consequently, the travel of the new control valve ($\%Travel_{revamp}$) would be 47, as highlighted in Figure 8.

3. Increased diesel production. Diesel has the highest value among all products from a middle-distillate-oriented hydrocracker. Primarily, the petroleum refinery in this example tries to minimize the cut point between kerosene and diesel to maximize its diesel production. Unfortunately, the existing diesel pump limits the diesel production at 199.4 m^3/hr from a high motor load. According to the refinery economist, the diesel production capacity should be expanded to 226.0 m^3/hr (at the pumping temperature). Possible solutions include either revamping both existing diesel pumps or adding a third larger pump.

Installing one pump is obviously a less expensive solution than replacing two pumps. In the end, the refinery decided to install the third larger pump (Figure 9). This new pump will be the main workhorse, with the existing pumps as spares, and will be offline only when there is low diesel load.

As pointed out earlier, diesel is the most expensive refinery product. Therefore, the refinery often ran both existing pumps in parallel to maximize diesel production. The only problem with this operation is that the existing pumps cannot be offline for regular maintenance. Furthermore, the liquid level inside the diesel-side stripper was sometimes unstable when the diesel hydrotreater was run at high throughput (two diesel streams from both units join together), forcing the refinery to reduce diesel production, due to the unstable level control valve.

As the worst-case scenario, the design engineer conducted the test run at the design revamp flowrate (Q_{revamp}, 226.0 m^3/hr) with the diesel hydrotreater at its maximum throughput. During the test run, both diesel pumps were in parallel operation, with *%Travel* of the level control valve at 95 (less than 80 is preferable). Based on Q_{revamp}, the baseline pump's head (ΔH_{base}) is 159.7 m, as graphically determined from Figure 10.

This diesel rundown system consists of long and complex pipelines, plus multiple heat exchangers, thus requiring challenging and expensive demolition work during the turnaround if it was modified. Hence, the new diesel pump will be sized so *%Travel* of the level control valve is around 60, by including a design margin (ΔH_{margin}) as per Equation 7.

$$\Delta H_{revamp} = \Delta H_{base} + \Delta H_{margin} \quad (7)$$

According to the study, the revamp pump's head (ΔH_{revamp}) must be 175.7 m to ensure good operability. In this case, a new relief valve is unavoidable due to higher shut-off pressure, but the additional cost is trivial considering the benefits.

4. Improved diesel recovery. A crude-petroleum distillation unit suffered from high pressure, resulting in lower diesel recovery. As per the design, the suction pressure of the overhead compressor directly sets the column pressure (Figure 11). The pressure-control system varies *%Travel* of the discharge control valve to maintain a constant accumulator pressure. When the *%Travel* reaches 100%, for example, at a

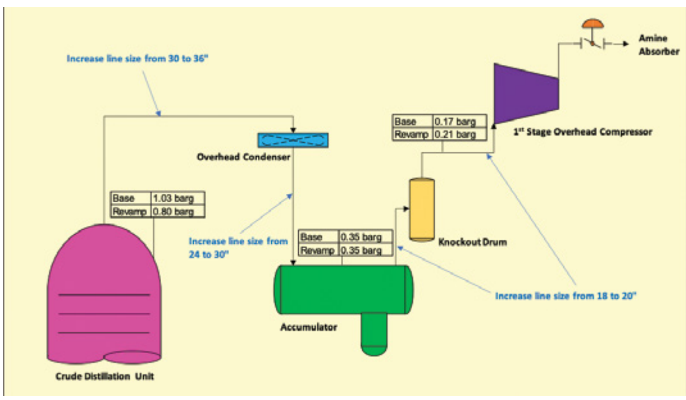


FIGURE 11. The illustration shows the crude distillation overhead system in Example 4. One can consider reducing the suction pressure drop as a fast-track solution to unload the overhead compressor, as highlighted here

TABLE 5. TEST-RUN DATA AND CALCULATION RESULTS FOR THE WASH-WATER SYSTEM REVAMP

	Base	Revamp	Maximum
Q, m^3/hour	150.2	200.6	210
$\%Travel_{main}$	48	91	100
$\%Travel_{bypass}$	100	100	100
$C_{v,main}$	1.00	4.23	4.91
$C_{v,bypass}$	4.91	4.91	4.91
$C_{v,total}$	5.91	9.14	9.82

high vapor flowrate, the accumulator and column pressure become uncontrolled and increase with even higher vapor flow. In this case, there are two possible options to improve diesel recovery: revamp the overhead compressor; or reduce suction piping pressure drop.

Replacing the overhead compressor would cost several million dollars. To avoid such a costly revamp, reducing suction-piping pressure drop to free up compressor capacity may be considered. As suggested by Ref. 4, raising suction pressure is the most effective way to unload compressor capacity, compared with discharge pressure and suction temperature reduction, especially in lower-pressure applications, such as atmospheric distillation. This capacity unloading is mainly due to a reduced gas volume from higher vapor density and increased condensation at higher suction pressure.

In other words, the operating point is shifted to the left of the polytropic head curve ($\Delta H_{polytropic}$, Figure 12), so the discharge control valve can retake control, such as with *%Travel* less than 80.

As a first step, the design engineer conducted multiple test runs at high throughputs. Flowrate, temperature, pressure and stream composition were recorded and verified as recommended in the previous sections. In this case, a full hydraulic model is unavoidable. Before optimizing a revamp solution, the hydraulic model was calibrated and tested against multiple sets of test-run data to ensure its validity.

As illustrated in Figure 11, it is possible to reduce the column's top pressure by 0.23 bar at the same accumulator pressure (with a total pressure drop reduction of 0.27 bar) by upgrading piping sections on the suction side. In this case, the piping replacement costs one-sixth the cost of an overhead compressor revamp.

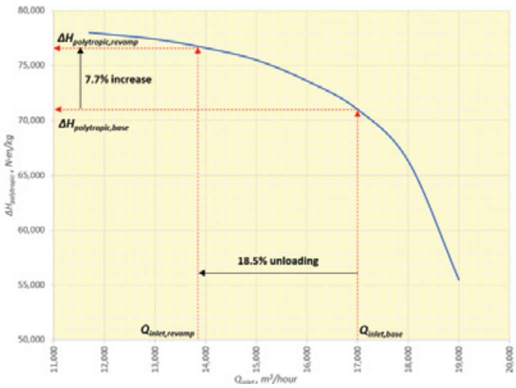


FIGURE 12. The graph shows how moving the operating point to the left of the polytropic head curve unloads the compressor discussed in example 4

Additional tips

The following tips should also be considered for revamps involving hydraulic limits:

- One can always increase a pump's head by replacing the impeller. API 610 requires that the casing of a new pump should be large enough to accommodate a larger impeller, so a 5% head increase is possible.
- In contrast with general belief, the head rise to shutoff (from the rated point) could be as low as 5% for a single pump operation (and could be even lower as per Ref. 5). According to API 610, a minimum of 10% head rise is for pumps in parallel. Nonetheless, many EPC contractors adopt 10% as a design criterion for all scenarios. This misunderstanding could result in unnecessary modifications. For example, a design engineer might need to add a relief valve into the existing system as the new shutoff pressure exceeds the piping design pressure from a suboptimal head rise to shutoff. For revamp scenarios, the operating point tends to be on the far right of the head curve (near the maximum throughput). In other words, the operating point will not change that often, as the plant owner always tries to push the production unit to its limit. Therefore, a head curve that is somewhat flat should be acceptable.
- Always conduct a pulsation analysis (per API 674 and 618) before adding new parallel reciprocating equipment to avoid possible piping and structural failures.
- Where can be applicable, design engineers should reuse equipment and devices that are no longer fit for their original service in a different service to minimize capital expenditures
- When engineers exploit design margins, the equipment or device will operate closer to its limits, thus narrowing operating ranges. This risk may be managed by adopting better monitoring and control, such as, adding a digital positioner to a control valve. ■

Edited by Scott Jenkins

Acknowledgements

The author would like to specially thank the following colleagues for their help in assembling this article:

- Thanawat Upienpong, Thanasan Thangchaksuwan, and Steven McMurray from PTT Global Chemical for sharing useful information, photos, and opinions.
- Wiroon Tanthapanichakoon from Global R&D and Meng Loong Chua from Shell Catalysts & Technologies for helpful comments.

References

1. Zhu, F. and others. "Efficient Petrochemical Processes: Technology, Design and Operation," Wiley, Hoboken, N.J., October 2019.
2. GPSA Midstream Suppliers, GPSA Engineering Databook, 13th Edition, 2019
3. Crane Co., Flow of Fluids Through Valves, Fittings, and Pipe, Technical Paper No. 410M, Vervante, 2009.
4. Golden, S. and others, Understanding centrifugal compressor performance, *Petroleum Technology Quarterly*, April 2002.
5. Chaware, D. and Joshi, A. Refinery specs: the user's view, *World Pumps*, February 2014.

Author

Nattapong Pongboot is an experienced chemical engineer with a broad range of experience in refining and petrochemical technologies. Before partnering with Global R&D (Address: Samut Prakarn, 10270 Thailand; Emails: nattapong.globalrd@gmail.com or nat.pongboot@gmail.com; Phone: +66-87-665-6015 (Thailand)), he held various technical roles with Honeywell UOP, PTT Global Chemical and SCG Chemicals with good exposure to process and equipment design, refinery operation, plant troubleshooting and process optimization. Additionally, he is also a technical instructor for www.chemengedu.com. He obtained both B.Eng (ChE) and M.Eng. (ChE) degree from Kasetsart University.

Revamps and Retrofits: A Path to 'Evergreen' Facilities

An intelligent approach to developing the scope of retrofit projects can allow facilities to remain competitive in the marketplace and meet regulatory requirements

Alan McCurdy
Valdes Engineering (ret.)

Timely and well executed retrofit projects are critical for most facilities in the chemical process industries (CPI) as they strive to remain competitive players in the marketplace, meet the owner's business needs and maintain regulatory compliance. Retrofit projects and new-facility projects lie on a spectrum, with the two having many similar requirements and qualities (Figure 1). With a sustainable plan and schedule, retrofit projects can be accomplished incrementally. The benefit of this approach is an "evergreen" facility that is responsive to business needs. This article focuses on scope development for revamp and retrofit projects, and presents many of the important considerations for undertaking a retrofit project.

Retrofit versus revamp

A "revamp project" replaces or upgrades equipment or systems to increase production capability or performance in an existing facility or industrial site. A "retrofit project" modifies, enhances, debottlenecks, or otherwise improves an existing entity, rather than involving the creation of an entirely new entity. In contrast, a new or "greenfield" project involves building a new facility on a new site (a greenfield), and is unconstrained by existing facilities. For the purposes of this article, these project types (retrofits and revamps) are considered identical.

Cost-benefit considerations

There are many factors at play in determining the scope, as well as the costs and benefits for a retrofit project. The following are a set of questions that should be worked through as the retrofit project begins.

Does the retrofit involve a "replacement-in-kind" of equipment? In cases where capital equipment may need to be replaced, it is often useful to start with how long the equipment has been in service. Most capital equipment is expected to have a 20-year minimum service life. If equipment is being replaced before the expected service life, determine whether there is a deficiency in design, reliability, performance, controls or installation. Here are some possibilities to consider:

- The application might require a different type of equipment
- The required reliability might demand a different metallurgy or service factor
- The normal and peak operating requirements might exceed the equipment's rating
- A more sophisticated control strategy might be required. For example, a pump with intermittent operations might require a discharge control valve, bypass line or variable-frequency drive to minimize pump starts and stops
- The equipment installation might put excessive mechanical or hydraulic stresses on the equipment or connections. For example, high temperatures can cause significant pipe expansion, which will require expansion joints, or a design that has adequate flexibility
- For critical equipment, the schedule might require a replacement-in-kind while a longer-term solution is developed and implemented

FIGURE 1. It is often the case that making improvements to CPI facilities is more cost-effective than replacing them

FIGURE 2. Improvements in equipment may require changes to the plant's infrastructure

These are only some of the factors justifying an "upgrade" instead of a "replacement-in-kind".

Is the retrofit an upgrade or enhancement project? If the equipment has been in service for a significant period, have there been technological improvements since the last installation? Improvements in equipment design, reliability, performance and efficiency are generally always occurring. For example, like automobiles and household ap-

pliances, industrial equipment has become automated, with significant benefits. Metallurgies have become more specialized, with alloys to reduce corrosion. Piping and electrical standards might have improved. The connecting pipe and electrical service might need to be upgraded.

Are safety or environmental performance upgrades required? Because they are already in operation, certain processes at CPI facilities are exempt from new standards (that is, they are "grandfathered" into meeting the requirements of the new standard). However, if it is part of a retrofit project, a process might require upgrades for safety, efficiency or environmental performance. For example, environmental and reliability requirements might require some rotating equipment to have sophisticated shaft-seal systems with barrier fluids.

Have equipment manufacturers consolidated, relocated, or gone out of business? Equipment considered "state of the art" twenty years ago, might not be available or might not meet current standards.

Will infrastructure changes be required? Improvements of new equipment might require an upgrade of the infrastructure (Figure 2). For example, automated equipment will need data connectivity. With different metallurgies and standards, the process and utility tie-in scope might need to include more pipe, electrical or controls scope. Different equipment designs might have different footprints, with different connections, support requirements and access points. If a process is being upgraded, the decisions become more complex. The scope might require the upgrade of a system with increased or different utility requirements.

Is the retrofit project a capacity increase or a debottlenecking project? A "bottleneck" constrains or limits a process. Bottlenecks can be identified in the manufacturing process by reviewing operating data and by modeling the process. An example is a manual drum-loading step in a manufacturing process. If a capacity increase is expected, the entire process will need to be evaluated to confirm the capacity is feasible. Review the current process and facility drawings, equipment and building layouts, and hazardous area classification drawings.

Some examples of debottlenecking projects include the following: An automated bulk charging system can improve cycle times by reducing the process charging time. Installing a larger pump or heat exchanger may not provide a production increase if the process and utilities inputs and outputs do not meet the new equipment's requirements. Keep in mind, though that higher flows might require larger pipe diameters to prevent high velocities (erosion) or high pressure drop (inefficiency). Also, heat exchangers are designed for certain fluid velocities for best heat transfer efficiency. As with piping, higher flows might require larger flow areas. Due to hydraulics and residence time, processing vessels and towers have certain high- and low-flow requirements for best operation.

Plan and scope development

The next phase of the retrofit project involves developing process flow diagrams, piping & instrumentation diagrams (P&IDs) and layout drawings of the retrofit options. "Redline" changes should be made to the existing facility design. These could include changes to piping connections for utilities, vents, drains and controls. Also note changes to valves for operation, isolation and bleeds. Consider access for construction, operations and maintenance.

The boundaries of a retrofit project need to be considered: In a retrofit project, the facility and supporting utilities are expected to be reused (with maybe selective upgrades). Otherwise, the project becomes a "new facility" project, not a retrofit. As an analogy using houses, a retrofit is "remodeling" not a "tear down" project. Installing more equipment in a fixed area will reduce operations and maintenance access. A larger footprint might encroach on setbacks from administrative areas and property lines. The existing facility will be reused, although the unit will likely be idled for the duration of the demolition (removal of replaced assets) and installation of new assets.

Design and execution planning

Planning is critical to any project's success. Many of these requirements are identical to any medium- to large-sized project, whether a retrofit or new facility. The design of the new retrofit assets needs to be integrated into the operations and maintenance procedures. Otherwise, there is a risk of unintended issues and inefficiencies.

Consider the owner's project resources. An owner has operating and maintenance staff with tasks and objectives assigned by management. Taking on project team responsibilities for a retrofit project will require a realignment of responsibilities. Engineering consultants can undertake the effort needed to support a retrofit project. However, the owner's personnel will still need to support the consultant with operational knowledge and approve final decisions. The scope of new or reused infrastructure needs to be balanced with cost, schedule and performance.

In planning, plant engineers must be cognizant of the required design

TERI / OGI Process Equipment, Spring Sands, Okla.

FIGURE 3. Process outages are required to install new equipment, such as the heater shown here

FIGURE 4. Prefabricated buildings, such as the control room shown here, may be prepared off-site and installed later

standards and codes. They should ask whether there are performance and efficiency requirements for new or reused utilities, and environmental systems. Also, there may be new or tie-ins to safety systems, such as new vents or relief valves, or tie-ins to exhaust systems. The operating environment and permitted operations should also be considered for potential hazards.

Normally, a process outage is required to dismantle and remove the existing equipment before installing the new equipment (Figure 3).

Projects may require changes to plant infrastructure, so the necessary tie-ins to piping, electrical and controls and utilities should be clear, as well as the need for potential new concrete and steel buildings for the storage and warehousing of raw materials or final product. There may be a need for new environmental systems.

Infrastructure requirements

If changes to plant infrastructure are required because of a retrofit project, there are several guidelines that should be followed.

- Consider access requirements for operations and maintenance staff. Instead of ladders, platforms might be needed, for example, especially if tools and equipment are required at the access point. Davits or overhead rails might be needed for removal of equipment
- Consider the impact of the infrastructure changes to owner's and external stakeholders. Where there are impacts, contact the appropriate owner stakeholder and evaluate the current environmental permit limits. Also, consider the current zoning of the owner's facility. Requirements waived due to grandfathering might be required for a retrofitted facility. If the amount of impervious surface is increased due to the infrastructure changes, then the stormwater runoff systems need to be evaluated
- Consider operator training and appropriate staffing levels (for startup and operations)

MoC and risk review

Whenever there are new processes being introduced or existing processes being revised, a management-of-change (MoC) approach should be used to systematically evaluate new and revised processes.

At major project milestones, safety and risk reviews should occur, particularly when making funding and permitting decisions.

Procurement

Planning is needed for the specifications, bidding and deliveries of critical equipment. The general best practice is to include the owner's purchasing agents early in the project schedule. At this stage, master service agreements and terms and conditions for the project will need to be established.

When making bid award decisions, the technical capabilities of the vendor companies involved should be carefully considered along with the pricing. Vendor construction, startup and follow-up support capabilities should be taken into account.

When assembling a procurement plan, spare-parts inventories for new equipment should be a part of the process.

Determine what items are "specialties," which would be purchased individually with specifications, and what items are treated as "bulk," meaning they can be purchased by the construction contractor.

Construction and startup

Determine the schedule for project approval, design, procurement, construction and startup. Include outage planning also for retrofit projects. New facilities can be constructed in parallel (or remotely) to an operating facility.

For the construction schedule, the following items should be considered:

- Appropriate level of off-site prework may be desirable, such as skid fabrication for equipment, pipe spools, prefabricated buildings and enclosures (Figure 4)
- Consider logistics (road permits and access to the site)
- Make piping tie-ins with valves at a more convenient time during a maintenance outage
- Make electrical tie-ins during maintenance outages. For example, install a motor starter or motor control center for project motors

Remember that the construction contractor's personnel and equipment will need access to the facility for parking, administrative facilities and material laydown areas, as well as physical access for work

The level of fabrication and construction inspections is important. Normally inspections are performed by either the owner's contractors or third-party contractors. There will be documentation requirements for the owner's regulatory groups and permitting requirement for municipalities and agencies.

At the conclusion of the retrofit project construction, operations and maintenance personnel will be needed for checkout, and construction personnel are needed to resolve punch-list item resolution. In addition, vendor personnel will be needed for the startup of specialized equipment. ■

Edited by Scott Jenkins

Author

Alan McCurdy retired from Valdes Engineering Co. (100 22nd Street, Lombard, IL 60148; Email: alan.mccurdy54@gmail.com) in 2020, but remains active part-time in certain projects. He has 40 years of experience as a project manager of engineering projects in pertroleum refining, chemical manufacturing, natural gas utilities and industrial facility settings. As a senior project manager at Valdes, McCurdy sheparded engineering design projects from concept to design and procurement and construction to startup. McCurdy holds a B.S.Ch.E. from Carnegie Mellon University (1976) and an MBA from the University of Louisville (1985). McCurdy has extensive knowledge of procedures and tools used by his employers, clients and associates, as well as analytics and tools from his MBA courses and quality and statistics training. In addition, McCurdy was a member of the U.S. Army from 1976 to 1980.

Gear Pump Basics

The versatile nature of gear-pump technology allows operators to handle multiple fluids in multiple applications

Michael Coburn and Geoff VanLeeuwen
PSG, a Dover company

Pump technology can be traced as far back as the B.C. era, when ancient Egyptians used a shadoof to move water from one source (in this instance, wells) to another. While basic in nature, this set the stage for others to follow, such as the ancient Greeks, who developed the first concept for a reciprocating pump, to Nicolas Grollier de Serviere, a Frenchman who created the early design for a gear pump near the back end of the 1500s.

Pump technology has substantially evolved since those times and is now woven into the fabric of everyday life.

Pumps can be found in a range of applications, such as tank trucks, ships, trains, manufacturing plants, storage tanks and bulk storage facilities, to name just a few. While water was one of the first liquids to be moved via pump, the technology has evolved to handle many other fluids. Gear pumps, for example, are designed to move an expansive range of critical commodities, including crude petroleum, biofuels, refined fuels, chemicals, solvents and food-grade materials.

While many pumping technologies have been developed and optimized throughout history, the gear pump stands out for its versatility, efficiency and longevity. These pumps, which come in internal or external designs, have endured multiple applications and fluids across time and continue to provide operators with several distinct advantages over comparable technologies.

This article discusses those advantages and explains why gear pumps remain a popular choice for operators across several sectors of the chemical process industries (CPI) when handling a range of liquids.

A closer look at gear pumps

Gear pumps create flow by pushing liquid through a mesh of teeth from two or more rotating gears (Figure 1). A drive shaft moves one gear, and that motion moves the other gear. The rotating gears form a liquid seal inside the casing, creating a vacuum at the inlet as the gear teeth separate. Liquid flows into the space and moves around the outer edge of the gears. Once the teeth meet again by the outlet, the gears force the liquid out.

Gear pumps come with either an internal or external configuration. External gear pumps use two separate shafts to support two interlocking gears, which form a mesh at the center of the pump to move fluid along. External gear pumps are known to use either helical, spur or herringbone gears to move liquid through the pump.

A similar principle is used in the internal configuration, but with two interlocking gears of different sizes (Figure 2, left). The smaller gear rotates within the larger gear, which has cavities instead of protruding teeth. An idler pin and a bushing attached to the pump casing keep the smaller gear, also known as the idler, in an off-center position, allowing it to interlock with the external gear's cavities. A fixed, crescent-shaped spacer serves as a seal between the pump's ports and fills the void from the smaller gear's off-center position (Figure 2, right).

Consisting of few moving parts, gear pumps deliver a constant amount of liquid with each revolution of their gears, with their tight clearances and rotational speed preventing slippage during operation. Because the gears are rigid, these pumps create a smooth, pulse-free flow, while also being fully capable of handling high-pumping pressures, a necessary trait when handling high-viscosity fluids.

Components (not) galore

When looking closer at the advantages of gear pumps over similar pump technologies, it's best to start internally (Figure 3). Gear pumps do not have many moving parts, regardless of configuration. In the external gear setup, two gears mesh to process liquid. Separate shafts support those two gears, which serve as the primary components of the pump. Internal gear pumps consist of a rotor (larger gear) and an idler (smaller gear), as well as an idler pin, bushing and a crescent-shaped partition.

In either setup, the number of components is minimal, meaning operators don't have to worry about having a massive stockpile of extra components on hand in case of failure. Having fewer components also means not having to worry about so many moving parts breaking down. Whether external or internal, both gear pump variations do not require constant shutdowns to replace different components with varying lifecycles.

When it comes to a shutdown for

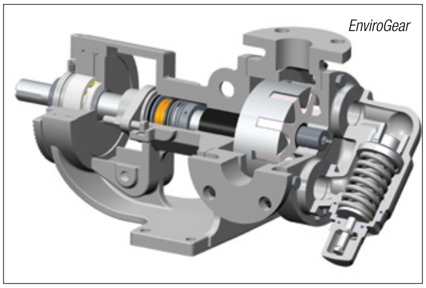


FIGURE 1. Gear pumps create flow by pushing liquid through a mesh of teeth from two or more rotating gears

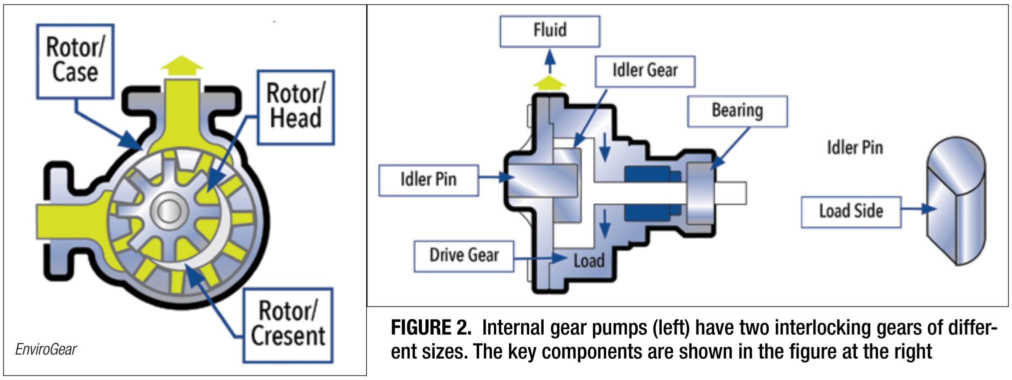


FIGURE 2. Internal gear pumps (left) have two interlocking gears of different sizes. The key components are shown in the figure at the right

the sake of maintenance, gear pump operators only have a few components to evaluate and service. This speeds up and simplifies the maintenance process, giving operators more time to focus on other tasks instead of dedicating too much time to an array of moving parts with different service requirements.

Should a component, such as a gear, fail, operators only have to open the pump and replace the part and put it back online. This is a less tedious procedure compared with other pumping technologies. Additionally, operators can service most gear pumps without removing them from the base, making it easier to service and put back online.

Tight internal clearances

When it comes to handling liquids of varying viscosities, tight internal clearances become essential to the success of the pump. Gear pumps are the kings of tight internal clearances, which makes sense given their composition. Once again, internal or external configurations create close tolerances and suction due to their design. Meshing gears do not leave any room for slippage because of the tight fit.

In gear pumps, the tightest clearances are found in the rotor/case, rotor/head and rotor/crescent mesh. Properly selected clearances insure efficient transfer of many liquids across a wide range of pressures and speeds. Aggressive liquids or liquids with solids can be accommodated in many cases by opening clearances within the pump. Examples of these include food-based products, paints and coatings, sealants, adhesives, epoxy resins, rubbers and detergents.

Some products, however, can cause major damage to pumping technology. One such substance is asphalt, which can range from a solid to a liquid, depending on the temperature, and has several fluid characteristics. Asphalt also comes in several variations, which include hot-mix asphalt, emulsified asphalt and filled asphalt.

Hot-mix asphalt can vary in viscosity based on temperature and contains a blend of high-quality aggregates, polymers and liquid asphalt cement. Emulsified asphalt is made from a mixture of asphalt cement, water and a surfactant (emulsifying agent), which makes it susceptible to shearing. Filled asphalt is highly abrasive because it contains limestone and other particles at concentrations of 60 to 70%.

While many pumps would fail at handling asphalt and its variations, gear pumps have a robust nature and appropriate internal clearances that aid in processing it. Gear pumps, though, require a break-in period to handle asphalt. After that, gear pumps can handle asphalt without damaging its components.

Robust by design

When it comes to highly corrosive fluids, many operators turn to internal gear pumps because they can be constructed to better handle them. Their design already provides an advantage, as discussed with the tight clearances. While gear pumps typically are made from stainless steel or cast iron, they are not limited to these materials.

When handling highly abrasive fluids, gear pumps can be designed using composites or alloys that allow them to process corrosive liquids, such as sulfuric acid and sodium hydroxide. Carbon steel is another option that provides the proper strength to handle aggressive liquids.

Another option to reduce costs, but not sacrifice performance is ductile iron. Using this material in gear pumps provides the same performance as steel without the costs associated with it. This is especially helpful when costs are a concern and an operator requires larger gear pumps for their application.

Steady flow

Gear pumps thrive under varying flowrates (Figure 4), allowing operators to place them in multiple applications with different demands. While some pumps need higher pressures for proper functionality or back pressure to avoid flow instability, gear pumps can function well under different flow conditions.

Gear pumps are designed to handle the same repeatable displacement regardless of the pressure. Mechanical volume displacement provides a much more repeatable fluid movement through the pressure range, providing operators with accurate flow control.

Being able to operate at varying flows means gear pumps do not suffer from the perils of constant high-flow pressures. Operators can push high flows and scale them back, de-

FIGURE 3. This breakaway diagram shows the components of an internal gear pump

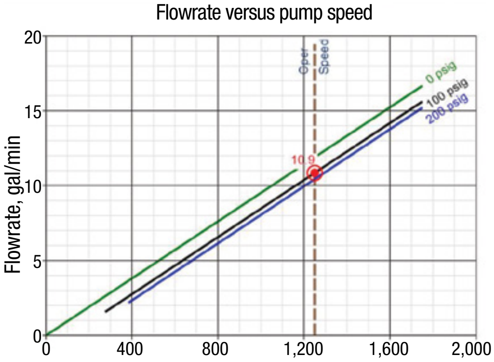


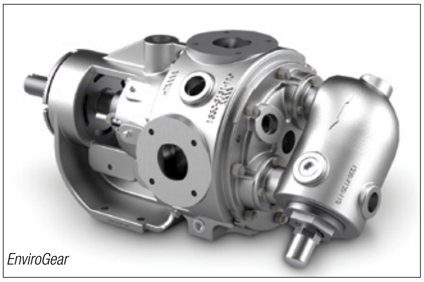
FIGURE 4. Gear pumps deliver a linear flowrate with speed over a wide range of pressure

pending on the application. The flow variation means gear pumps will not be susceptible to accelerated wear-and-tear on the pump internals from consistent high flows. The varying flows will allow the gear pump to have better longevity.

Temperatures can vary

Being able to handle a wide temperature range is imperative to pumping technology if an operator needs it for a variety of applications with different internal and external conditions. Gear pumps perform exceptionally well in nearly all temperature conditions due to having a wide range of tolerances.

Gear pumps can successfully operate in temperatures as low as –112°F (–80°C) and process fluids with temperatures as high as 800°F (425°C). Having this type of flexibility allows gear pumps to accept several liquids of varying temperatures — from soaps and surfactants to asphalts and adhesives — while also operating in environments with extreme weather fluctuations. That means that gear pumps can operate just as effectively with these fluids in the northern-most regions of Canada to the equator regions of South America.



EnviroGear

FIGURE 5. Gear pumps can be jacketed to maintain the temperature in applications such as asphalt handling

Additionally, gear pumps are designed to accept jacketing (Figure 5) across most of their surface area, a key feature that allows this technology to retain heat for substances that require it, such as asphalt. Operators can jacket up to 70–80% of the gear pump's surface area, allowing the apparatus to retain heat effectively. This means most of the gear pumps will keep hot liquids at the proper temperature without the risk of solids forming due to cold spots.

Possibilities with all viscosities

Some pump technologies are limited when it comes to the thickness or thin nature of the fluid. Gear pumps, however, can process a vast range of fluid viscosities. The interlocking gears can accept fluids as low as 1 centipoise (cP) or as high as 1,000,000 cP.

This dynamic range gives operators with gear pumps the ability to run several different fluids through them without incident. That means operators do not have to outfit a plant with several different pumping technologies for varying fluid properties. They can rely on gear pumps to reliably and efficiently handle several different viscosities. ■

Edited by Gerald Ondrey

Authors

Michael Coburn is the Enviro-Gear product manager at Blackmer (1809 Century Avenue SW, Grand Rapids, MI 49503; Email: michael.coburn@psgdover.com) — PSG, a Dover company (Oakbrook Terrace, IL; www.psgdover.com). Prior to this, he has worked at Attwood Corp., Biomet Microfixation and W. Lorenz Surgical, He holds a B.S.M.E. degree from Grand Valley State University.

Geoff VanLeeuwen is a product management director for Blackmer and PSG. (same address as above; Email: geoff.vanleeuwen@psgdover.com). Prior to his 7 years with PSG, he worked at Sargent & Lundy and Innotec. VanLeeuwen has an M.B.A. degree from Grand Valley State University, A masters of engineering from the University of Illinois at Chicago, and a B.S.M.E. degree from Calvin College. He is a licensed Professional Engineer in Illinois and Michigan.

Pump Seals to Manage Water

Paying attention to the seal design used in centrifugal pumps can help in water management. This article uses the beverage industry to illustrate this point

Heinz Bloch
Process Machinery Consulting

Economic survival in a climate where industry competition and environmental concerns converge is not easy. However, protecting the planet is becoming an ethical imperative for reasonable people. It is — or should be — matched only by an acute sense of self-preservation.

It gives us pleasure when we see these priorities beginning to line up nicely with legitimate and logical commercial interests. Commercial interests can rightly be summarized as low-cost production and high equipment reliability. That said, this article introduces the reader to factual details, proven achievements, and realistic goals as they pertain to the beverage industry.

Sustainability targets

In the beverage industry, targets are typically expressed as water-use ratio, or liters of water consumed per liter of beverage produced. Singling out the beer brewing industry, an entity fittingly using the acronym BIER (Beer Industry Environmental Roundtable) published benchmarking studies that show a steady improvement from 2013 to 2017 with the water-use ratio from 2.76 L/L (0.73 gal/gal) to 2.53 L/L (0.67 gal/gal) — an improvement of 8.3%.

In the beer-brewing segment of the beverage industry, the water-use ratio declined from 3.68 L/L (0.98 gal/gal) in 2017 to 3.35L/L (0.89 gal/gal) in 2018. This represents a welcome 9% reduction. However, many of today's brewers have more ambitious targets and are reaching these by paying attention to pump-seal water-management matters.

Upgrade options

Modern breweries operate dozens of centrifugal pumps; these move liquids ranging from light slurries to ultra-clean final products. In the final products, even trace contaminants (solids) would be objectionable and proper sealing is important.

One of many possible mechanical seal configurations is generally used to seal between the pump casing and the rotating shaft. Such seals work by having two very flat surfaces, one connected to the rotating shaft, and the other connected to the stationary casing. Spring pressure is applied to one of the two faces, and pumpage cannot escape with the pump stopped and the seal faces contacting. When the pump rotates, the faces open about one micron, a gap approximately fifty times smaller than the diameter of a human hair. A miniscule volume of flush passes between the faces, thereby providing both lubrication and heat removal. For years, relatively low-cost mechanical seals similar to Figure 1 were used with water as the flush liquid.

In the decades since 1970, industry has applied the tried and tested seal configurations and seal flush applications described in the standards of the American Petroleum Institute (API). Among these we find the typical mechanical seal in Figure 1. Here, seal flush water can be connected to the top of the outer port. This water would contact the inside of a mechanical seal assembly and then exit from a diagonally opposite port to drain. If the user opted to connect flush water to the larger of the two flush ports, the flush liquid would mingle with the liquid contained between the impeller and taper-bored pump back plate. It would thus dilute the pumpage and, in many cases, would later have to be removed by evaporative means. Vacuum dehydration or evaporation (or both) by applying heat are among the available means of water removal, but both contribute to a facility's operating expenses and wasted water, a valuable resource.

Usage figures tell the story. Suppose a user passes cool clean water through the smaller of the two flush entry ports and releases it to drain. In the brewing industry, this water flow is set to around 5.7 L/min (1.52 gal/min) per pump, which equates to about 3 million L (~800,000 gal) per pump per year. But suppose the user would be shown a well-proven way of elimi-

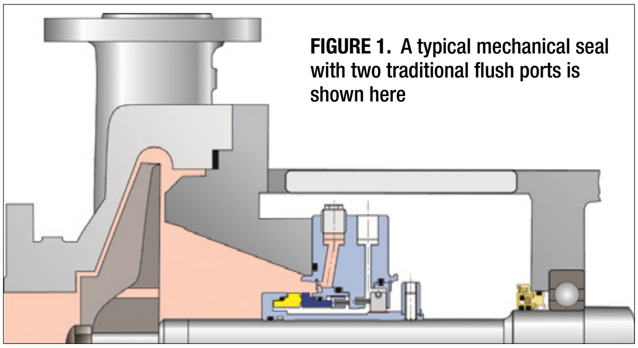


FIGURE 1. A typical mechanical seal with two traditional flush ports is shown here

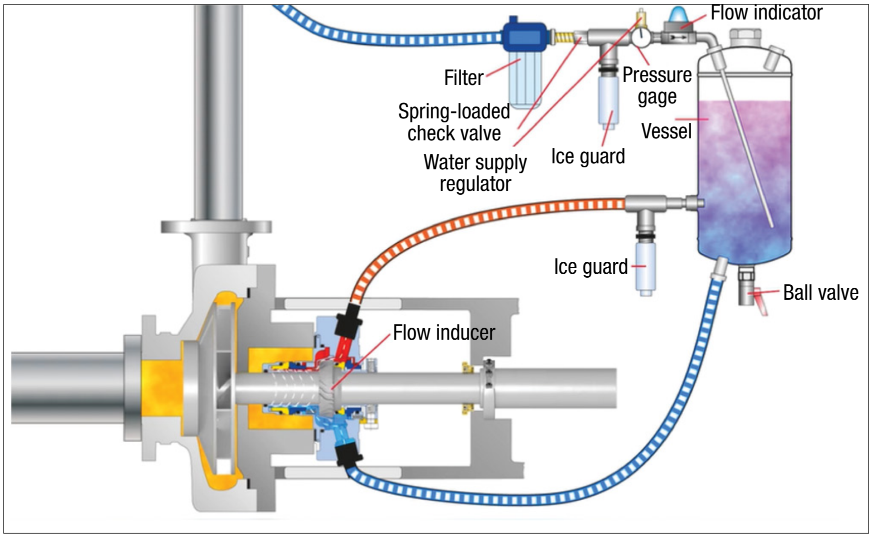


FIGURE 2. A self-contained (closed loop) seal water-management system is shown here (Source: AESSEAL, Inc., Rotherham, UK, and Knoxville, Tenn.)

nating 5.7 L/min (1.52 gal/min) of water use from 25 pumps. The user would thereby reduce water consumption by 74.9 million L/yr (~20 million gal/yr).

We had taken the average brewery's numbers 740,812,000,000 L of water used and 221,106,000,000 L of beer produced from the BIER 2018 Benchmarking Study. The water-use ratio thus equaled 3.35. Accordingly, the new water-use ratio of 3.03 L/L translates into a reduction of 10%.

Water management systems

More recently, these reductions have been well documented [*1*]. The uneconomic ways of seal flushing described earlier are being superseded by the water management system shown in Figure 2.

This is a closed-loop system that recirculates the water in the mechanical seal. The system is pressurized by the plant's water supply, ensuring that product remains in the pump. A flow indication instrument monitors system condition and readily detects leakage. Water management systems all but eliminate any significant consumption of seal water.

The vessel shown in Figure 2 is designed with a quick-release clamp allowing the bottom section of the tank to be removed for inspection and cleaning. Experienced manufacturers offer materials that are considered safe for use in food production.

Cost and potential ROI

Industry data suggest the benefits of eliminating the flow of sealing water and treatment of wastewater. Using the numbers in this article for 25 typical centrifugal pumps, yearly savings of $113,000 will be realized. The simple payback (return on investment; ROI) on this application will be less than 12 months in addition to gaining a 10% reduction in water-use ratio. In essence, all parties — including the environment — will benefit from this proven sealing technology. ■

Edited by Gerald Ondrey

Reference

1. Perez, Robert X. and Bloch, Heinz P., "Pump Wisdom: Essential Centrifugal Pump Knowledge for Operators and Specialists," 2nd Ed., John Wiley & Sons, Hoboken, N.J., 2021.

Author

Heinz P. Bloch is a consulting engineer at Process Machinery Consulting, and resides in Montgomery, Tex. (heinzpbloch@gmail.com). His professional career commenced in 1962 and included long-term assignments as Exxon Chemical's Regional Machinery Specialist for the U.S. He has authored or co-written over 790 publications, among them 24 comprehensive books on practical machinery management, failure analysis, failure avoidance, compressors, steam turbines, pumps, oil mist lubrication and optimized lubrication for industry. Bloch holds B.S. and M.S. degrees (cum laude) in mechanical engineering from the New Jersey Institute of Technology. He is an ASME Life Fellow and was awarded life-time registration as a Professional Engineer in New Jersey.

Critical Components in Regenerative Thermal Oxidizers: High-Cycle Valves

When designing a regenerative thermal oxidizer, engineers should not overlook the high-cycle valves that control process air and help maintain efficiency

Anu D. Vij
Ship & Shore Environmental

Regenerative thermal oxidizers (RTOs) are regularly utilized in the chemical process industries (CPI) to collect and control air-pollution emissions generated from industrial manufacturing operations. RTOs are specially designed for controlling emissions of volatile organic compounds (VOCs) from a broad spectrum of industries. An RTO uses ceramic media as the heat-exchanger medium, providing high heat recoveries. For the last decade, a great deal of emphasis has been placed on the selection of the ceramic media and burners for RTOs, while some of the most critical components of RTO operation — high-cycle valves — have been overlooked.

The purpose of high-cycle valves in an RTO is to provide tight shutoff of the process air to maintain destruction and removal efficiency (DRE) and proper heat-exchanger operation for thermal energy recovery. High-cycle valves serve to regulate the flow of air and to isolate ducting and equipment for maintenance without interrupting other connected units. Without this valve, the regenerative process is unattainable.

High-cycle valve designs should consider the maximum system pressure, temperature changes and stresses imposed by the connecting ducting so as to prevent distortion and misalignment of the sealing surfaces. The sealing surfaces should be of such material and design that the valve will supply a tight seal over a reasonable service period. Proper valve design is critical for high VOC destruction efficiency over a long equipment life. Cycling more than 200,000 times per year, RTO high-cycle valves must operate reliably and must seal to less than 0.1% leakage at full system pressure.

FIGURE 1. This two-canister regenerative thermal oxidizer (RTO) is equipped with high-cycle horizontal poppet valves

High-cycle valve types

Generally, two kinds of valves are used in RTOs. High-cycle valves are connected directly to the RTO's heat-exchanger canisters, directing the flow of process air into and out of the canisters, which need to open and close every few minutes (typically 1 to 3 minutes) on a continuous basis. Most other valves associated with RTOs are called low-cycle valves due to their lower cycling frequency. Examples of low-cycle valves include isolation and diverter valves.

This article focuses exclusively on high-cycle valves, which are critical to the overall performance of an RTO — namely to achieving high destruction efficiencies. Figure 1 depicts a typical two-canister oxidizer with high-cycle horizontal poppet valves.

RTO designs can be classified into three categories: single-canister, odd-canister and even-canister designs. The style of high-cycle valve used is determined by the canister design. Some commonly available high-cycle valve designs used in RTOs include the following:

- Butterfly valves (including single-blade, dual-blade and dual-seat valves)
- Poppet valves (including single-poppet, dual-poppet and four-way poppet valves)
- Single-canister rotary valve
- Two-canister, high-cycle, rotating-flow reversal indexing valve

Other important issues to consider when selecting high-cycle valves for RTO applications include the following:

- Valve seat material — options include metal-to-metal seats or ceramic (soft)
- Valve actuation mode — options include hydraulic, pneumatic or electric
- Maximum allowable leakage rate — typically 0 to 0.25%
- Materials of construction
- Resistance to condensable organics and other particulate matter

High-cycle butterfly valves

High-cycle butterfly valves (Figure 2) have been used in RTOs for more than 40 years. Consisting of a heavy-gauge flat plate inserted into a gas stream, the high-cycle valve plate is rotated by means of a motor (actuator) and linkage to control the gas-stream flow. When the valve is in the fully open position, the flat plate is aligned with the direction of gas flow and, therefore, provides very little flow restriction.

Butterfly valves occupy less space than any other valve style and have broad versatility due to the virtue of their design. They are relatively tight-sealing when proper torque is applied. They offer a simple and reliable means of gas control for both modulating and on-off applications.

To actuate (for opening or closing), butterfly valves employ a center-mounted rotating disc (or discs that typically rotate 90 deg.) The solid rotating disc, which is generally round, must resist thermal and mechanical deformations. The type and size of the valve dictates the torque

requirements and, by extension, the actuation requirements. For example, beyond a certain torque, pneumatic actuators become less desirable than hydraulic dampers due to their size.

Butterfly valves used in regenerative thermal oxidizers typically are the on-off type with two design variations.

The single-blade valve is the most common type. It consists of a single solid disc (or blade) that seats against a metal or a compressible-bulb (ceramic) seal.

The double-blade valve is used when zero leakage is required, usually in applications where very high destruction efficiencies are desired. Double-bladed dampers also are supplied with either a metal or a ceramic seat.

High-cycle poppet valves

Throughout the U.S. and in Europe, poppet valves have been used for over 25 years in two- and multi-canister RTOs. They consist of a flat circular plate that is raised or lowered typically by an electrical or pneumatic actuator. When the flat plate is in the closed position, it provides a gas seal by pressing against a raised circular seat. Gas attempting to pass through the cylinder is blocked. When the valve disk moves laterally, there are 12 to 24 in. between its open and closed position. Note that poppet valves are used for on-off control only — they are not appropriate for modulating applications (Figure 3).

Poppet valves were initially developed for service in fabric filter systems or baghouses, and later successfully applied to RTOs. Fabric filter systems require two-way service with poppets either open or closed. System-outlet poppets are single-disc, low-leak models. System bypass poppets are leak-free, and employ a double blade and seat with seal air. These valves range from 20 to 60 in. in diameter for industrial baghouses and 48 to over 96 in. in diameter for power-generation baghouses.

Poppets for RTO service are more complex in that they seal multiple gas paths while diverting gas in different directions. RTO systems designed with two-way poppets should have one inlet and one outlet damper, providing fail-safe conditions during power outages and upset operating

FIGURE 2. High-cycle butterfly valves used in RTOs will employ a flat valve plate that is mechanically rotated to control gas flow

conditions. RTO poppet valves of this type are driven pneumatically or electrically for high-cycle service and low-leakage isolation. Pneumatics or electric drive systems supply the most reliable type of drive movement for service where 200,000 cycles per year are expected. Poppets of this type operate best when oriented vertically. They are also available with zero-leak blades and seats.

Poppet valves with three-way and four-way configurations have also been used in RTO systems. A three-way poppet has one inlet and two outlets. It cycles between two seats, diverting flow through one while sealing the other and vice versa. A four-way poppet has two inlets and two outlets, and is typically used in compact RTO systems.

Single-canister rotary valves

The single-canister rotary valve design eliminates the need for separate inlet, outlet and purge valves by replacing them with a single large valve. Rotary valve designs have been applied to RTOs for over 20 years. The sequence of the multiple-valve bed function as an inlet, outlet or purge is achieved by the rotation of this single valve. This valve is located below the heat recovery chambers and is either electrically or hydraulically driven. The rotation of the valve, or the flow distributor, continuously controls the airflow from the inlet plenum to one-half of the heat exchange media through the combustion retention chamber, through the other half of the heat exchange media, and then out through the outlet plenum.

The cylindrical canister holds 12 pie-shaped heat-recovery chambers. The air is cycled through six inlet chambers for preheating and through six outlet chambers for reheating the heat exchanger bed before exiting. Before chambers switch from inlet to outlet flow, they are purged of any residual unoxidized gas. Between each set of heat-recovery chambers, there are two additional chambers. One of these chambers is closed off while the second is used to purge. This purging ensures minimal VOC spikes and maximizes destruction efficiency.

The single valve moves at several minutes per rotation and ensures a smooth transition from inlet-to-purge to outlet-to-purge. This reduces upstream pressure fluctuations, which are more typical with traditional individual-canister RTO designs. The single valve, in some instances, depending on the type of traditional valve-drive system, requires less maintenance compared to the multiple-valve RTO system.

However, a single-canister rotary valve utilizes a machined metal-to-metal surface (sealed air-floating rings are used to minimize metal-to-metal contact) to achieve tight seal-

FIGURE 3. High-cycle poppet valve systems are designed for on-off control, rather than modulating applications

FIGURE 4. A flow-reversal indexing valve provides a zero-leakage design that utilizes a high-pressure air seal

ing. This makes it more susceptible to wear and tear. This seating arrangement also makes the single-canister RTOs more susceptible to particulate contamination, resulting in lost performance over time due to inorganic particulate wearing on the machined metal-to-metal surfaces. Other problems, such as shaft bushing malfunction and metal deformation due to high temperatures hitting the valve, have also been reported.

Flow-reversal indexing valves

The high-cycle poppet and single-canister rotary-valve system is made up of many moving parts. All of these reciprocating parts must be driven simultaneously during the valve shaft's 0.5- to 1.0-s linear seat-to-seat sudden start/stop valve movement. A simple wear-based failure of even one of these many pneumatic electro-mechanically driven parts, such as a pneumatic cylinder seal failure or pneumatic component temperature freeze, can cause the entire system to malfunction. At worst, the entire RTO system goes down, or at a minimum, poppet seat leakage reduces VOC destruction beyond the point of destruction compliance during its 200,000 valve cycles per year.

Conversely, another valve type — high-cycle flow-reversal indexing valves — can offer zero leakage in an assembly that has only one moving part. Each 90-deg index rotation of the shaft-interconnected flow diverter assembly reverses flow through the valve and interconnected RTO system. Simply put, each rotational valve movement (typically less than 0.5 s) reverses flow through the RTO.

Indexing valve designs feature no VOC leakage seals and no stopping contact seats. Rather, they are sealed using high-pressure air, which is supplied by an integral compressor blower, whose clean air separates the inlet and exhaust sides of the valve (Figure 4). This valve requires no duct manifolds, as the valve is equipped with one duct-mounting flange on each of its four ports — a valve duct connection to the inlet port from the process; an exhaust port duct to the stack; a port duct to chamber 1; and a port duct to chamber 2.

Indexing rotation is supplied by a single, intermittently operated electric-motor drive system that uses electrical power for 0.5 s per movement. It is preprogrammed for same-direction 90-deg indexing of the diverter assembly on contact closure command, which ensures that it always stops at its same predestinated position each time, even after a utility power failure. Electrically, all that is required by the end user is a momentary contact closure to initiate movement. If so desired, as an option, it can also be same-direction rotated using a single pneumatic cylinder. ■

Edited by Mary Page Bailey

Author

Anu D. Vij is chief operating officer (COO) of Ship & Shore Environmental Inc. (2474 N. Palm Drive, Signal Hill, CA 90755; Phone: (562) 997-0233; Email: avij@shipandshore.com; Website: www.shipandshore.com). Vij has over twenty years of experience in the environmental, chemical, petrochemical and air-pollution-control industries, and has specific expertise in thermal oxidation technologies. As COO at Ship & Shore, he oversees several business units, including sales, finance, engineering, project management, procurement, production and services. Prior to joining Ship & Shore, Vij served as vice president, enclosed combustion systems, at Aereon and was director of engineering at OnQuest Inc. Vij holds an M.S.Ch.E. from the University of Southern California and a B.S.Ch.E. from Panjab University in India.

2019 | 2020 | 2021

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Sept. '21 Prelim.	Aug. '21 Final	Sept. '20 Final
CE Index	754.7	735.2	593.7
Equipment	947.5	918.6	717.2
Heat exchangers & tanks	813.2	784.8	605.8
Process machinery	958.5	921.1	717.9
Pipe, valves & fittings	1,330.9	1,304.7	954.0
Process instruments	551.3	541.3	422.1
Pumps & compressors	1,180.5	1,148.8	1,084.0
Electrical equipment	639.3	616.8	565.0
Structural supports & misc.	1,038.9	1,000.4	752.7
Construction labor	348.6	347.4	337.6
Buildings	772.0	767.5	616.1
Engineering & supervision	311.1	310.2	311.8

Annual Index:

2013 = 567.3

2014 = 576.1

2015 = 556.8

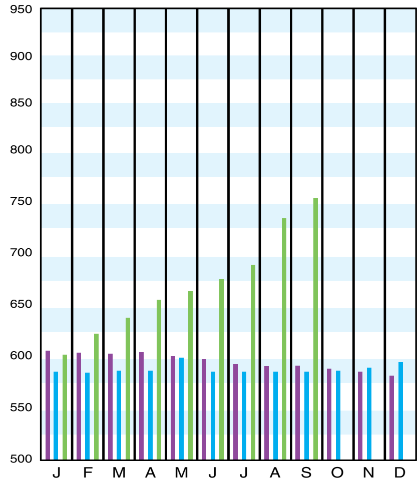
2016 = 541.7

2017 = 567.5

2018 = 603.1

2019 = 607.5

2020 = 596.2

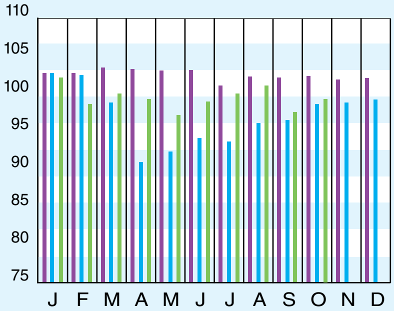


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

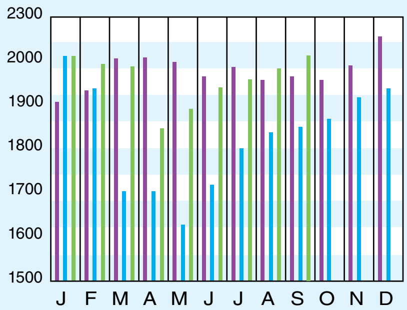
CURRENT BUSINESS INDICATORS

CURRENT BUSINESS INDICATORS	LATEST	PREVIOUS		YEAR AGO
CPI output index (2017 = 100)	Oct. '21 = 98.5	Sept. '21 = 97.3	Aug. '21 = 98.3	Oct. '20 = 93.9
CPI value of output, $ billions	Sept. '21 = 2,005.4	Aug. '21 = 1,984.9	Jul. '21 = 1,966.0	Sept. '20 = 1,672.2
CPI operating rate, %	Oct. '21 = 78.5	Sept. '21 = 77.6	Aug. '21 = 78.4	Oct. '20 = 74.6
Producer prices, industrial chemicals (1982 = 100)	Oct. '21 = 335.4	Sept. '21 = 345.2	Aug. '21 = 331.0	Oct. '20 = 227.7
Industrial Production in Manufacturing (2017 =100)*	Oct. '21 = 99.8	Sept. '21 = 98.6	Aug. '21 = 99.3	Oct. '20 = 95.6
Hourly earnings index, chemical & allied products (1992 = 100)	Oct. '21 = 195.9	Sept. '21 = 198.3	Aug. '21 = 193.6	Oct. '20 = 188.6
Productivity index, chemicals & allied products (1992 = 100)	Oct. '21 = 95.4	Sept. '21 = 94.4	Aug. '21 = 356.0	Oct. '20 = 90.4

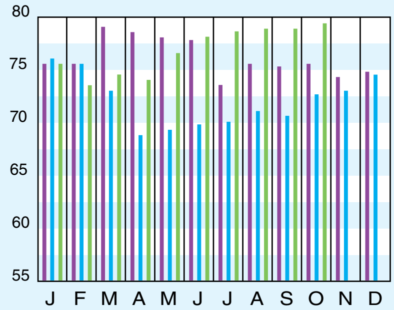
CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for September 2021 (most recent available) continues the streak of rapid monthly increases observed since the beginning of the year. The Index topped 750, after beginning the year at around 600. In September, all four major subindices (Equipment, Construction Labor, Buildings and Engineering & Supervision) saw upticks, with the Equipment subindex showing the largest gain. The current CEPCI value is 27.1% higher than the corresponding value from September 2020. Meanwhile, the Current Business Indicators (middle) show rises in the CPI Output Index and the CPI Operating Rate for October 2021, and a rise in the CPI Value of Output for September.